Seismicity and Surface Deformation of Mauna Loa Volcano, Hawaii

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Changing patterns of seismicity and surface deformation indicate that magma is being injected and stored in a shallow reservoir beneath the summit, and that the probability of an eruption is increased.

Introduction

Mauna Loa is a 4169-m-high shield volcano on the Island of Hawaii. Its latest two eruptions occurred on the southwest flank in 1950 [*Macdonald*, 1954] and, mainly within the summit caldera, in 1975 [*Lockwood et al.*, 1976]. The oval summit caldera is 8 by 5 km in diameter, with cliffs as much as 180 m high (Figure 1). It is elongate in the direction of two principal rift zones that extend northeastward and southwestward from the summit. These rift zones, which are commonly vents for flank eruptions, form the gently sloping ridges that give Mauna Loa its Hawaiian name—Long Mountain.

Flows beheaded by the caldera have been radiocarbon dated as young as 500 ± 70 years, which is therefore the maximum age for the latest episode of major caldera collapse on Mauna Loa. The caldera was 120 m deeper in 1841 than at present [*Macdonald*, 1971], but it is now filled to the point where voluminous summit flows spill out from its low south end.

Increased seismicity beneath Mauna Loa precedes at least some eruptions [*Eaton*, 1962; *Koyanagi et al.*, 1975]. In addition, surface deformation, as expressed by widening of the caldera, was detected by electronic-distance-measurement (EDM) survey lines during the year before the 1975 eruption. Both the distribution of earthquake hypocenters beneath Mauna Loa and the pattern of surface deformation are important evidence for interpreting the presence, size, and depth of shallow magma reservoirs beneath Mauna Loa.

The data presented in this report come from the combined efforts of the entire staff of the Hawaiian Volcano Observatory from 1962 to the present.

Seismicity

Figures 2 through 6 plot the distribution of earthquakes in time and space beneath the summit region of Mauna Loa. The earthquake locations have been obtained from an increasingly sophisticated network of seismic stations that now number 47 on the Island of Hawaii. To eliminate any bias from the increased number and better distribution of seismometers, only earthquakes of magnitude equal to or larger than 2.0 with horizontal and vertical location uncertainties of less than 2 km are plotted in Figures 2 to 6. The location limit of the present seismometer network for a shallow (0–5 km) earthquake beneath the summit of Mauna Loa is about magnitude 0.5.

Figure 2 shows the cumulative number of earthquakes of magnitude equal to or greater than 2.0 at three different depths (shallow, 0–5 km; intermediate, 5–13 km; deep, 13–50 km) beneath Mauna Loa since 1962. Between 1962 and 1974, the rate of events in all three categories was about the same—only 2 to 3 earthquakes per year within each depth range. Beginning in 1974, however, the number of intermediate-depth earthquakes picked up sharply and was soon followed by an even larger increase in shallow earthquakes. During late 1974 and early 1975, the total number of microearthquakes recorded beneath Mauna Loa commonly exceeded several hundred per day. Intense swarms occurred in August and December 1974, and again from February through June 1975; the eruption began on July 5, 1975. Numerous microearthquakes and harmonic tremor accompanied this 20-hour eruption and continued until July 12, after lava emission had ceased. After that date, shallow earthquakes dropped to a very low rate, but intermediate-depth earthquakes continued at a fairly steady rate of 7 to 8 per year following the eruption. The number of deeper earthquakes per year was not affected by the eruption. Shallow earthquakes began to increase again in mid-1980, and their rate has generally continued to increase since then.

Figure 3 plots earthquake epicenters with respect to the summit caldera and rift zones of Mauna Loa. The principal pattern of shallow earthquakes (plus-sign symbols, 5–10-km depth) is a diffuse cluster slightly larger in diameter than the combined caldera and eastern ring fracture. Even though this shallow earthquake zone does not exactly coincide with the caldera, the zone is clearly related to the summit area of Mauna Loa. The other major cluster of epicenters (open-square symbols, 5–13-km depth) is 8 to 7 km west north-

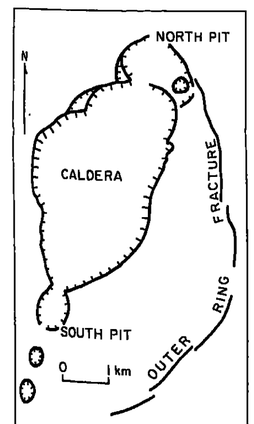

Fig. 1. Mauna Loa's summit caldera. Cliffs on west side of collapse caldera are as much as 180 m high. Lineations of fractures, craters, and vents called rift zones extend northeastward and southwestward from the caldera. Outer ring fracture is a zone of fissure and faulting with a few meters subsidence on the caldera side.

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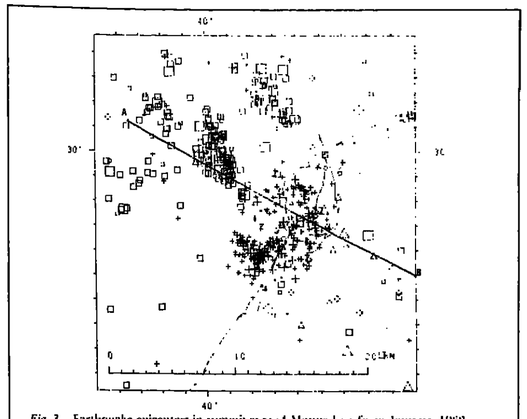

Fig. 3. Earthquake epicenters in summit area of Mauna Loa from January 1962 through May 1983. Plus signs, shallow (0–5 km) earthquakes; open squares, intermediate-depth (5–13 km) earthquakes; open diamonds, deeper (13–20 km) earthquakes; open triangles, deepest (20–30 km) earthquakes. Size of each symbol is an indication of magnitude; smallest marks represent earthquakes of magnitude 2.0 to 2.9, and largest marks represent earthquakes of magnitude 4.0 to 4.9. A–B, line of cross section in Figure 4. Lines extending northeastward and southwestward from the summit caldera denote surface fractures along rift zones.

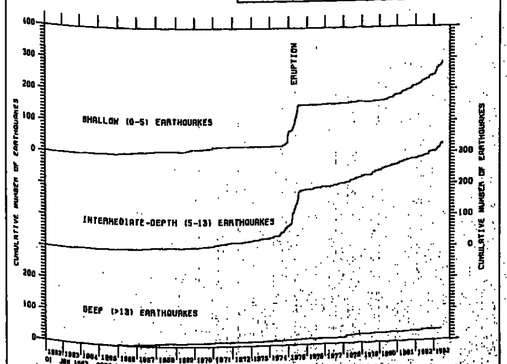

Fig. 2. Cumulative number of earthquakes of magnitude equal to or greater than 2.0 beneath summit region of Mauna Loa, plotted against time.

Editorial

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Article *(cont. from p. 545)*

west of the center of the caldera, at a depth of about 5 to 7 km. A third cluster of earthquake sources (open-triangle symbols, below 20-km depth), evident only in cross section (Figure 4), occurs beneath Mauna Loa's summit at a depth of about 40 km.

Figure 5 plots the earthquake epicenters on Mauna Loa during the 18-month period before the July 1975 eruption, and Figure 6 plots those during the past 18 months (December 1981 through May 1983). The total number of earthquakes is lower during the past 18 months, and many of the shallow earthquakes are more tightly clustered on the southwest side of the caldera. The overall patterns of seismicity, however, are generally similar.

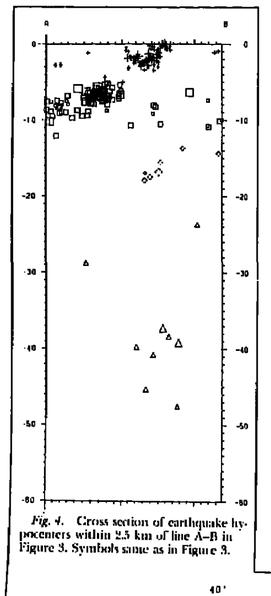

Fig. 4. Cross section of earthquake hypocenters within 2.5 km of line A–B in Figure 3. Symbols same as in Figure 3.

The shallow earthquakes in the summit area are interpreted to occur in brittle rocks capping a zone of magma storage. The stresses causing these earthquakes apparently arise from changes in pressure and volume of the magma reservoir as well as from steep thermal gradients.

The intermediate-depth earthquakes west of the summit may be caused by stresses from the wedging effects of shallow dikes emplaced along the summit caldera and rift zones. The upper parts of Mauna Loa must spread horizontally in a northwestward or southeastward direction to accommodate the cumulative thickness of dikes in the rift zone. These 1- to 2-m-thick dikes make up a zone a few kilometers wide, emplaced over the past 10,000 to 100,000 years.

The deeper cluster of earthquake hypocenters, about 40 km beneath the summit, may be caused by the opening and closing of deep feeder conduits between the mantle magma source and the higher magma-storage reservoirs. The low but continuous rate of these deep earthquakes supports an interpretation of a fairly steady magma supply into Mauna Loa from a deep source. This magma is then stored in higher level reservoirs and released intermittently to the surface to generate eruptions.

The zones with very few or no earthquake hypocenters may be either zones of low stress or zones with low rigidity. The empty zone between the shallow and deep clusters of earthquake hypocenters directly beneath the caldera (Figure 4) is unlikely to be a zone of low or unchanging stresses. This zone is more probably a region of low rigidity occupied, at least in part, by magma.

Ground Deformation

Leveling lines and EDM-survey lines near and across the caldera were started in 1964. These monitors showed no significant changes until 1974 and 1975, when the amount of extension of some of the cross-caldera lines amounted to slightly more than 100 mm. Figure 7 plots the locations of the present leveling, tilt, and EDM stations on Mauna Loa, many of which were established just before or after the 1975 eruption. Figure 8 plots the sudden widening of the caldera by at least 600 mm in 1975; that dilation was apparently caused by emplacement of the dike that fed the summit eruption of July 5–6, 1975. After this eruption, extension of the cross-caldera lines continued at a rate of about 200 mm yr^{-1} into 1976 and has continued since then at rates of about 20 to 50 mm yr^{-1}.

The spirit-level tilt measurements are made by precise, repeated optical levels on stadia rods placed at bench marks arranged in a triangle with approximately 30- to 40-m-base legs [*Yamashita*, 1981]. This technique has a precision of about 10 microradians. Figure 9 plots tilt-measurement results with rate changes similar to those shown by the EDM data plotted in Figure 8. Rapid outward tilt (inflation) occurred for 1 year after the eruption, followed by more moderate, though continuous, inflation since 1976.

Figures 10 through 13 show the total leveling, tilt, and EDM changes from 1977 to 1981. Figure 10 compares the theoretical uplift from a pressure increase at 3.1-km depth [*Mogi*, 1958] with the observed inflation. Figure 11 shows the observed extensions across the caldera, and the corresponding best-fit displacements are shown as solid vectors in Figure 12. The dashed vectors in Figure 12 are those expected from the theoretical inflation of the surface of an elastic half-space due to an increase in pressure 3.2 km beneath the apex of inflation. Figure 13 compares the observed tilt changes (solid vectors) with those predicted by the elastic model (dashed vectors). These data alone indicate a more shallow depth (2.6 km) to the pressure source beneath the apex of inflation.

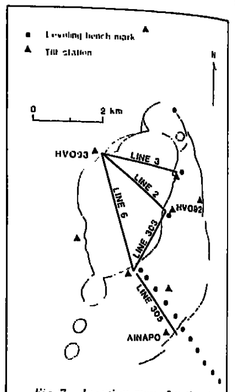

Fig. 7. Location map of stations for surface-deformation measurements in summit area of Mauna Loa.

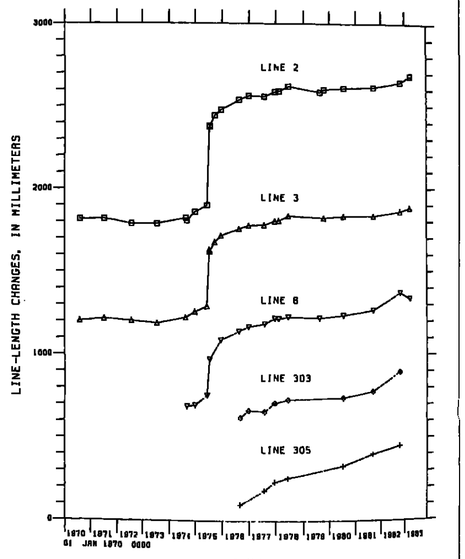

Fig. 8. Changes in EDM-survey lines across summit area of Mauna Loa (See Figure 7 for locations of lines). Sudden extensions in 1975 were caused by emplacement of dike that fed the eruption. Persistent extension since 1975 indicates continuing inflation of summit region of Mauna Loa.

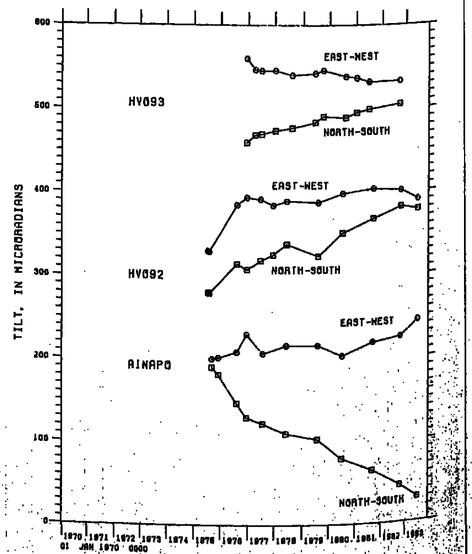

Fig. 9. Changes in north-south (up–down) and east–west (up–down) tilt components in summit area of Mauna Loa since 1975 (see Figure 7 for locations of stations). Station HV093 shows persistent northwestward tilting, station HV092 persistent north-northeastward tilting, and station AINAPO persistent south-southeastward tilting. These tilt changes indicate inflation of summit region of Mauna Loa.

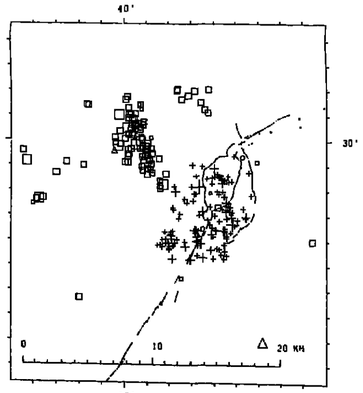

Fig. 5. Earthquake epicenters in summit area of Mauna Loa from January 1974 through June 1975. Symbols same as in Figure 3.

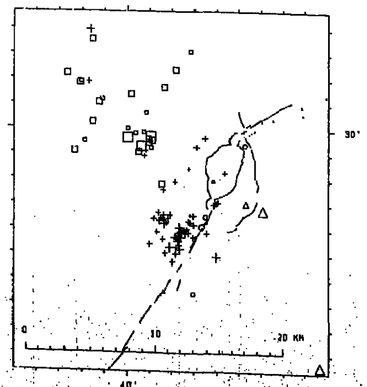

Fig. 6. Earthquake epicenters in summit area of Mauna Loa from December 1981 through May 1983. Symbols same as in Figure 3.

Table 1 lists the various parameters obtained by inverting the leveling, tilt, and EDM data separately, and by simultaneous inversion of all the deformation data [*Dvorak et al.*, 1983]. The longitude and latitude of the apex of inflation are x and y, respectively, and z is the depth to the point pressure source beneath the apex of inflation. The volume values show for each data source the total volume of swelling, which represents the minimum volume of increased magma storage at depths of 3 to 4 km. The bulk rigidity and compressibility of the system are not known, and so accurate estimates cannot be made of magma-volume changes. The base values show the amounts of theoretical uplift of the reference bench mark needed to make the elastic model best fit the observations. The sigma values show the quality of fit between the least-squares model and the observations.

It is clear from all the deformation measurements that they fit a simple, elastic model reasonably well and that they define a common center of uplift and a surprisingly shallow pressure source. The similarity between the surface-deformation pattern of the summit areas of Mauna Loa and Kilauea volcanoes is striking. On Kilauea, the pressure source is about 3 km deep [*Fiske and Kinoshita*, 1969; *Swanson et al.*, 1976], and inflations and deflations of the summit area create leveling, tilt, and EDM changes with similar patterns to those measured on Mauna Loa. Even though the lower zones of the magma chambers beneath Mauna Loa and Kilauea reach to several kilometers depth on the basis of seismic evidence [*Koyanagi et al.*, 1975; *Ryan et al.*, 1981], the changes in surface deformation on both volcanoes indicate that the zone of active magma input and removal is quite shallow.

The major difference between Mauna Loa and Kilauea, indicated by the surface-deformation changes, is the rate of magma input. Table 1 shows that the recent magma supply rate to Mauna Loa causes an average surface-volume change of about 4×10^6 m^3 yr^{-1}. The actual volume of magma must equal or exceed this volume of inflation. During the same period, surface-volume changes at the summit of Kilauea indicate a magma supply of at least 60×10^6 m^3 yr^{-1} [*Dzurisin and Koyanagi*, 1981].

The similarity of the morphology and evolution of the calderas on Mauna Loa and Kilauea, and the recent discovery of an apparent caldera on Loihi, the young submarine volcano 50 km south of Kilauea [*Malahoff et al.*, 1982], indicate that the filling and collapse of calderas is a longlasting and common mechanism in the growth of Hawaiian volcanoes. This conclusion implies that the magma-storage zone grows upward from the old sea bottom as the volcano gains in elevation. This upward growth could lead to the evolution of a complex magma reservoir system whose diameter is about the same as that of the caldera and whose vertical height would extend from at least the old sea bottom (5 km below sea level) to 3 km beneath the summit of the volcano. The long-term supply of magma from the upper mantle at depths of about 50 km into this more shallow magma-reservoir complex would tend to form even deeper and wider roots to the total magma-reservoir system beneath the caldera. Figure 14 is a schematic cross section at true scale of one possible model of the magma-reservoir system beneath Mauna Loa. Zone A, the more active part of the magma-reservoir system, slowly inflates between eruptions, and rapidly deflates to supply magma to flank eruptions from the rift zones. Zone B, which also is a region of magma storage, is less active than zone A in the sense of less change in storage volume over time. Both zones are inferred to be networks of molten intrusions separated by screens of hot but more solid rock.

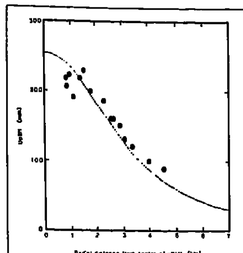

Fig. 10. Comparison of best-fit elastic deformation model (solid curve) with observed elevation changes from leveling surveys in summit area of Mauna Loa from 1977 to 1981 (see Figure 7 for locations of leveling bench marks). Reference bench mark is the most northerly dot in Figure 7. Depth to pressure source beneath summit for this model is 3.1 km.

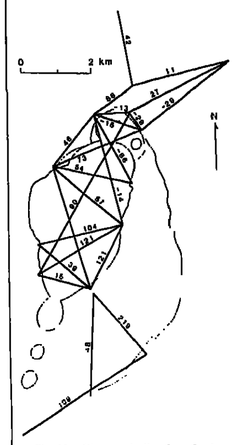

Fig. 11. Changes in line length of EDM-survey lines in summit area of Mauna Loa from 1977 to 1981. Positive values are extensions (in millimeters), and negative values are contractions (in millimeters). Maximum measured change is 100 microstrain units on line 305 (Figure 7), southeast of the caldera.

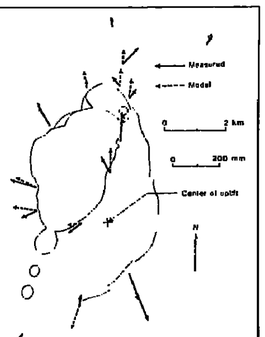

Fig. 12. Horizontal displacements calculated from EDM-survey line-length changes in Figure 10 (solid vectors) in comparison with those from best-fit elastic deformation model (dashed vectors). Vector scale shows displacement amplitudes (in millimeters) from 1977 to 1981. Center of uplift (apex of inflation) is surface projection of a buried point source of pressure 3.2 km beneath summit of Mauna Loa.

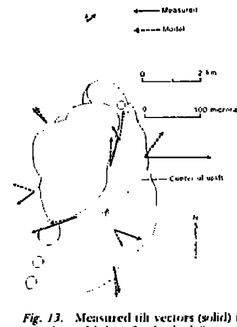

Fig. 13. Measured tilt vectors (solid) in comparison with best-fit elastic-deformation-model vectors (dashed). Tilt scale shows vector amplitudes (in microradians) between 1977 and 1981. Center of uplift is nearly identical to that independently determined in Figure 12, but buried point source of pressure for tilt data alone is 2.6 km.

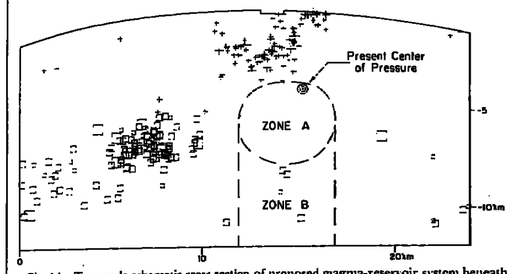

Fig. 14. True-scale schematic cross section of proposed magma-reservoir system beneath summit of Mauna Loa. Cross section and earthquake hypocenters same as in upper 12 km of Figure 4.

TABLE 1. Mauna Loa Geodetic Data, 1977–1981

	x		y					σ	σ EDM		
Data	Longitude W	km	Latitude N	km	z, km	Volume, 10^6 m^3	Base, mm	Level, mm	mm	μ strain	σ Tilt, μ rad
Leveling	156°34.5'	± 0.2	19°27.5'	± 0.2	3.1 ± 0.5	17 ± 8	59 ± 24	4			
Tilt	156°36.2'	± 0.6	19°27.5'	± 0.6	2.6 ± 1.2	8 ± 5					27
EDM	156°35.1'	± 0.7	19°27.2'	± 0.4	3.2 ± 1.2	19 ± 8			37	25	
All	156°35.0'	± 0.4	19°27.5'	± 0.3	3.0 ± 0.8	22 ± 6	88 ± 50	16	40	28	30

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Cover. Sulfuric acid aerosol droplets, collected with wire impactors over Baja California, before and after stratospheric perturbation by El Chichón. Pictures in the left column are from a collection taken April 19, 1982, at 21,300 m, after the main eruption of April 4, but before arrival of any part of the El Chichón cloud. Acid droplets are small and scarce (the linearly-arranged depressions are pits in the sample substrate) and represent a background aerosol amounting to about 0.7 ppb by mass of $SO_4^=$. Greatly increased El Chichón-derived aerosol burden is, however, evident on December 12 at 20,700 m. (right column). By this time significant amounts of the SO_2 gas introduced by El Chichón had converted to H_2SO_4. Droplets are large and abundant; the $SO_4^=$ level is 49 ppb. These examples are from a collection program using NASA U-2 aircraft. Thin sampling wires mounted in support rings are exposed at preselected altitudes; aerosol droplets impact the wires at aircraft speed, which is usually 740 km per hour. (Photographs courtesy of K. G. Snetsinger, G. V. Ferry, and V. R. Oberbeck, NASA Ames Research Center, Moffett Field, California; and D. M. Hayes, EAL Corporation, Richmond, California.)

Increased Eruption Probability

Mauna Loa last erupted in July 1975. That eruption was preceded by an increase in both shallow and intermediate-depth earthquakes, and by extension of EDM-survey lines across the caldera (Figures 2 and 8). Since 1980, and especially since early 1983, the number of shallow earthquakes beneath Mauna Loa has been increasing again. Intermediate-depth earthquakes have continued at a higher rate during the period from 1978 to the present than during 1971 to 1973 but have not shown the same pattern of increase as they did in 1974. Figure 8 (with the exception of line 6) also shows a recent increase in the rate of extension of EDM-survey lines across the summit caldera of Mauna Loa.

The near-surface strain from the apparent intrusion of magma beneath the summit region of Mauna Loa has recently shown an accelerating trend on the basis of both seismic and ground-surface-deformation data. But since the present strength of Mauna Loa is not known, no precise forecast of the next eruption can be made. However, if the present rate of strain continues to increase (and we emphasize the "if"), the probability significantly increases for an eruption of Mauna Loa during the next 2 years.

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Bob Decker is *scientist-in-charge of the U.S. Geological Survey's Hawaiian Volcano Observatory (HVO), a position he has held since 1979.* Bob Koyanagi *is senior seismologist and has been at HVO since 1961.* John Dvorak *specializes in interpretation of surface-deformation data; he has been at HVO since 1981.* Jack Lockwood *is the dean of Mauna Loa geology and has been at HVO since 1974.* Arnold Okamura *has been collecting and analyzing deformation data on Hawaiian volcanoes since 1961.* Ken Yamashita *is principal surveyor; he has been making surface-deformation measurements at HVO since 1965.* Wil Tanigawa *analyzes the records from the 47 seismic stations on Hawaii; he has been at HVO since 1979.*

News

In Congress

Budget Update for NOAA, USGS

Among the agenda items facing Congress as it reconvenes this week are the fiscal 1984 budgets for the National Oceanic and Atmospheric Administration (NOAA), which is part of the Department of Commerce, and for the U.S. Geological Survey (USGS), which is within the Department of the Interior. Fiscal year 1984 begins October 1, 1983. As Congress rolls up its shirtsleeves and gets down to business, *Eos* presents a status report on the two agency budgets.

Both House and Senate appropriations committees have finished their work on the NOAA budget, which had been targeted by President Ronald Reagan for a $799.8 million appropriation request (program level of $843.2 million) in his proposed fiscal 1984 budget (*Eos*, February 15, 1983, p. 65). The House appropriation for NOAA (H.R. 3134 and H.R. 3222) is $998.5 million, with a program level of $1043.9 million. The Senate Appropriations Committee set its appropriation (S. 1721) at $987.8 million, with a program level of $1041.0 million.

Appropriations are the amount of money the government will use from the treasury; program levels represent the actual money available. Program levels include not only appropriations from the federal government, but also supplementals, residuals from previous years, offsets from various funds, etc. (*Eos*, February 9, 1982, p. 148).

If the bills go to the floor of their respective houses and are passed, the differences between the House and Senate versions of the NOAA budget will be ironed out in a conference committee. A continuing resolution may be necessary, though, to keep NOAA running if the appropriations bills are not signed into law when the fiscal year begins. Table 1 compares the Reagan Administration request for program levels within the operations, research, and facilities (ORF) account, NOAA's largest, with the program levels from the House and Senate.

Appropriations for USGS have been passed by the full House as part of the Interior Department budget (H.R. 3363). On July 19, the Senate Appropriations Committee sent the bill to the full Senate, where it has since been under consideration. The Senate is expected to continue its consideration of the Interior budget when it reconvenes this week.

The House set the USGS appropriation at $383.5 million and its program level at $407.5 million, while the Senate Appropriations Committee agreed on an appropriation of $364.5 million and a program level of $388.5 million. Residual funds from previous years for the National Petroleum Reserve in Alaska are responsible for the $24 million difference between each house's appropriation and program levels. The differences between the House and Senate versions will have to be ironed out in a conference committee once the Senate passes the bill. Table 2 compares the Reagan Administration proposed budget with the House and Senate versions.—*BTR*

TABLE 1. NOAA Fiscal 1984 Budget Status: Operations, Research, and Facilities (ORF), in Thousands

Activity	Reagan Proposal	House Version[1]	Senate Version[2]
Ocean and Coastal Programs			
Nonliving marine resources	1,761	2,561	3,761
Ocean research	23,452	37,884	39,014
Ocean services	13,237	13,021	15,280
Sea Grant	0	35,000	38,000
Coastal zone management[3]	6,056		
Mapping, charting, and geodesy	72,619	45,139	47,089
Subtotal	117,125	133,605	143,144
Marine Fishery Resource Programs	92,444	141,550	144,292
Atmospheric Programs			
Public warning & forecasting services	264,996	298,581	301,959
Atmospheric and hydrologic research	44,501	49,696	51,496
Subtotal	309,497	348,277	353,455
Satellite and Environmental Data and Information Services			
Satellite services	73,279	71,479	71,479
Satellite systems	117,361	137,361	137,361
Data & information systems	22,313	23,313	22,791
Subtotal	212,953	231,153	231,631
Program Support	95,355	104,851	113,210
Total, ORF	827,372	959,436	985,732

Numbers may not total because of rounding.
[1]These numbers represent the program levels based on House budget appropriations for NOAA in H.R. 3134, reported by the House Appropriations Committee (Committee Report 98-234) on May 26 and in H.R. 3222 (Committee Report 98-232), June 3.
[2]These numbers represent the program levels based on Senate budget appropriations for NOAA (S. 1721), reported by the Senate Appropriations Committee (Committee Report 98-206) on July 28.
[3]Both the House and Senate put Coastal Zone Management into its own account. The House set the program level for CZM at roughly $37.4 million, while the Senate set the program level at $28.4 million. The total listed for the Reagan request for Ocean and Coastal Programs includes CZM; the totals for Congress' levels do not.

TABLE 2. USGS Fiscal 1984 Budget Status, in Millions

Activity	Reagan Proposal	House Version[1]	Senate Version[2]
Geologic and Mineral Resource Surveys			
Geologic hazards	40.7	52.4	48.7
Land resource surveys	16.7	18.1	16.7
Mineral resource surveys	45.3	45.3	45.3
Energy geologic surveys	25.5	34.0	29.5
Offshore geologic surveys	13.7	16.2	18.7
Subtotal	141.9	166.0	158.9
Water Resources Investigations			
National water data system-federal program	55.4	63.0	56.7
National water data system: federal-state cooperative program	47.1	49.6	47.6
Energy hydrology	9.6	12.6	12.1
Subtotal	112.1	125.2	116.4
National Mapping Program	77.9	93.1	90.0
Facilities	13.2	13.2	13.2
General Administration	14.2	15.5	15.6
Total, USGS	365.5[3]	407.5[3]	388.5[3]

Numbers may not total because of rounding.
[1]These numbers represent the program levels based on budget appropriations contained in H.R. 3363 and passed by the House of Representatives on June 28. Includes $24 million from residual funds for National Petroleum Reserve in Alaska (NPRA).
[2]These figures represent the program levels based on budget appropriations arrived at by the Senate Appropriations Committee (Committee Report 98-194) and reported to the Senate floor July 19. Includes $24 million for NPRA.
[3]Does not include money for NPRA. This total also includes $6 million for digital cartography activities, which in previous years had been included with the National Mapping Program activity but was listed separately in the fiscal 1984 Reagan proposal.
[4]These totals, which are not the sum of the activity levels, include a $5.6 million reduction for office rental costs.

Seabed Heat Transfer

The Subseabed Disposal Program (SDP) includes a set of heat-transfer experiments on the ocean floor, planned for 1986. The concept is to provide data on the local heating of seabed sediment released by buried radioactive waste materials. The In Situ Heat Transfer experiment (ISHTE) involves placing a 400-W isotopic heat source and related equipment frame on the seabed at a depth of approximately 6000 m. Data will be recorded at the site, some of which will be transmitted to a surface vessel by acoustic telemetry. The entire apparatus will be recovered within 1 year.

The program is being run as a collaborative effort among the Sandia National Laboratories, the University of Washington Applied Physics Laboratory, the University of Rhode Island Marine Geomechanics Laboratory, the Woods Hole Oceanographic Institution, and the Naval Ocean Research and Development Activity. The comprehensive ISHTE will measure the thermal field, the effective thermal conductivity of the sediment, pore pressure, radionuclide migration, and sediment shear strength and provide chemical analysis of pore water and sediment. Nuclear wastes may be stored in the future in canisters buried in the ocean floor clay sediments, and thus the clays must act as a major containment barrier for 10^4 to 10^5 years. The following questions are under study:

- The capacity of the sediment to transport thermal energy away from the canister to prevent overheating
- The capability of the sediment to securely restrain the canister from moving
- The chemical and mineralogical changes induced by thermally activated reactions
- Pressure buildup caused by thermal expansion of pore water
- The permeability change of the sediment induced by pore-water expansion and chemical alteration
- The radionuclide sorption characteristics of the sediments both in the heated region and the cooler regions remote from the canister

According to a report prepared by C. Mark Percival of Sandia Laboratories (SAND80-0202, May 1983), "The interactions are being investigated by analytical methods, computer models, and supporting laboratory experiments. The overall objectives of the model and laboratory studies are to develop means of predicting the long-term response of the waste/sediment system in order to define problem areas, propose solutions, develop an optimum system design, and assure that the design is safe.

"The approach to the model development," continues Percival, "is to form a physical/mathematical/computer description of a process; measure, as well as possible, associated phenomena and properties in the laboratory; make predictions and run confirming in situ experiments; and, finally, modify or improve the fundamental knowledge of the process and the predictive tools if required. At present, data and models to describe the heat-transfer, fluid-flow, geochemical, and radionuclide-migration processes in the seabed sediment are under development."

The primary objectives of ISHTE are: (1) to provide data on the effects of heating on the response (temperature excursions, pore pressure variations, pore fluid motion, tracer particle transport, thermochemical reactions, etc.) of in situ sediment for use in verifying laboratory experimental approaches and computer models; (2) to provide an opportunity to observe any unanticipated phenomena which may occur; and (3) to develop and demonstrate the technology necessary to perform waste isolation oriented experiments on and in the ocean bed at depths of 6000 m for an extended period of time, obtain large quantities of data, and recover the experiment.

Two points must be emphasized for this experiment. First, ISHTE is not a simulation of a waste emplacement. No effort has been made to scale canister sizes, power, or emplacement depths. The experiment is designed only to provide a body of data to test and to verify the accuracy and applicability of laboratory experimental approaches and computer models. Second, ISHTE is not solely a heat-transfer experiment. In addition to the energy transport data, information will be obtained on pore-fluid response, sediment/seawater/heater thermochemical reactions, sediment thermal stability, and the transport and sorption of injected tracer species.

Because of the high temperatures to be generated during ISHTE and the need for fine-grained, low-permeability sediments, a considerable effort has been devoted to selection of a suitable site. One of the controlling aspects is that the water pressure must be high enough to prevent boiling and possible abnormal thermally induced volume increases.

Several oceanographic research cruises have been concentrated in a region about 1800 km north of Hawaii in an area designated as MPG-1 between latitudes 30° and 31°30'N and longitudes 157° and 159°W. A great deal of data has been collected on the geological aspects of the region as well as the geotechnical and geochemical characteristics of the sediments to depths of over 24 m into the sediment layer. ISHTE could be performed at sites other than the proposed MPG-1 site. The site criteria listed above must be met and sufficient material characterization must be completed to provide the necessary thermal and mechanical properties for the model calculations.—*PMB*

Geoscientists Surveyed

A sociological survey of men and women geoscientists has been prepared by the Association for Women Geoscientists (AWG) in conjunction with the University of Colorado. AWG, which will mail the survey questions to its members in October, invites interested men and women who are not AWG members to request and fill out the questionnaire; it will be available October 1 from Sigrid Asher, 586 South Williams Street, Denver, CO 80209, and must be returned by October 31, 1983.

The survey will cover both career facts and job attitudes, and the results will be analyzed by survey specialists at the University of Colorado. AWG hopes that, besides being useful for designing AWG programs to meet the needs of those queried, the survey will provide employment statistics previously unavailable.

A national roster of AWG members, listing professional activities, educational background, and technical specialties will be published this fall.

AWG, a national professional organization, encourages the participation of women in the geosciences, promotes their professional advancement, and exchanges technical and professional information. Membership in AWG is open to all who support AWG goals.

AWG has recently initiated programs targeted on the community outside of the AWG membership. In addition to the sociological survey, it is currently working with the Girl Scouts of America to develop a geology field program to be offered to Girl Scouts in 1984. By 1984, AWG will have fully established the tax-exempt AWG Education Foundation. A non-profit public corporation, the AWG Foundation will provide awards, grants and scholarships to women studying the geosciences. Special emphasis will be placed on scholarships for women re-entering the profession and women doing graduate level studies.

Founded in 1977 by a small group in the San Francisco Bay area, AWG has since expanded to a membership of nearly 1000 men and women across the United States. The AWG program includes monthly chapter meetings which feature technical presentations; career development seminars sponsored by chapters and stressing opportunities for both students and professionals; workshops; and field trips.

Other services and activities provided by AWG include the national, bimonthly newsletter, *Gaea*, and local newsletters published by the chapters. (Gaea, pronounced "jee-a," is the name of the ancient Greek goddess of earth and is the root of the prefix "geo-.") A job clearinghouse, breakfasts, and booths at national SEG, AAPG and GSA meetings, and student awards are also regular AWG activities.

For individual or institutional membership information, the address of the chapter nearest you, or a nonmember subscription to *Gaea*, write to: Association for Women Geoscientists, P.O. Box 1005, Menlo Park, CA 94025.

Mobile VLBI Transfer

The National Aeronautics and Space Administration (NASA) has agreed to transfer Mobile Very Long Baseline Interferometry (VLBI) equipment and operations to the National Oceanic and Atmospheric Administration (NOAA). NOAA will use these mobile systems to create and maintain a National Crustal Motion Network (NCMN) and to support NASA's Crustal Dynamics Project. Consisting of several fixed VLBI sites across the United States, and 40 to 50 additional sites established by mobile VLBI, the NCMN will provide a basic terrestrial coordinate system throughout the United States that has been referenced to the inertial system defined by the fixed VLBI stations. While monitoring crustal deformation across the United States, the NCMN will also establish base stations in the National Networks of Geodetic Control that will also provide accuracy criteria for use with differential and interferometric Global Positioning System receivers. This NCMN will gain further importance as the burden of geodetic observations shifts increasingly to satellite-based techniques in the future.

The transfer to NOAA will take place from January 1983 to January 1985, during which time NOAA will provide trained operating crews and NASA will demonstrate the operational status of the systems and transfer their ownership to NOAA. These systems include three separate mobile VLBI systems as well as a fixed base station. The mobile VLBI systems consist of MV-1, the original ARIES 9-m-diameter antenna system; MV-2, the second ARIES system with a 4-m-diameter antenna; and MV-3, the ORION system with a 5-m-diameter antenna. The fixed system, designated the Mojave Base Station (MBS), uses a 12-m-diameter antenna located at the facilities of the Goldstone Deep Space Network in southern California.

All the mobile systems have been built and successfully demonstrated by the Jet Propulsion Laboratory (JPL) under contract to NASA's Crustal Dynamics Project. The Project is also responsible for the refurbishment of MBS, which will serve as the base station from which the mobile systems will be deployed and where they will be maintained between observing sessions.

The agreement calls for the transfer of MBS and MV-3 during January 1984 with transfer of MV-1 and MV-2 during January 1985. Training of a NOAA crew for MV-3 has already begun at JPL, and a contractor crew is also in training at MBS. The Geodetic Research and Development Laboratory branch of the National Geodetic Survey (NGS), National Ocean service, NOAA, will manage NOAA's mobile VLBI operation. The NOAA crew for MV-3 and the ground surveying for many of the sites is provided by the NGS Operations Branch.

VLBI measurements provide the greatest available accuracies for measuring baselines of hundreds or even thousands of kilometers. Typical uncertainties of a few centimeters will permit motions of the earth's crust along fault lines to be measured after repeated visits to selected sites over a few years. Gathering data to understand the relation between these subtle motions and earthquakes is a major impetus of the mobile VLBI program.

MV-1 was originally developed as a proof-of-concept instrument and consequently is not as highly mobile as subsequent systems. Assembling and disassembling its 9-m antenna at a new site takes about 14 days using a crew of at least four persons, along with a crane and a "cherry picker." Since 1975, MV-1 has occupied a dozen sites in California between La Jolla and San Francisco, using radio observatories in Owens Valley and Goldstone as base stations. Because of the time and expense of relocating MV-1, it is expected to serve as a semipermanent base station at Vandenberg Air Force Base through the 1988 completion of NASA's Crustal Dynamics Project.

Much greater mobility was achieved with MV-2, whose 4-m antenna system can be deployed in a few hours after arriving on site. MV-2 has been used since 1980 to occupy additional sites in California and Yuma, Arizona. MV-3 is the first mobile system designed specifically for the Crustal Dynamics Project. Designed and built entirely by JPL, it is intended to serve as a well-documented standard on which any future mobile VLBI system would be based. MV-3 began gathering data in 1982 and has greatly extended the range of mobile VLBI operations, traveling approximately 1920 km from Pasadena to Platteville, Colorado, during June 1983.

Typically, about 24 hours of continuous observations are desired at each site with about 1 or 2 days allowed before and after the observing sessions for setup, checkout, and teardown. Driven by diesel tractors, each mobile VLBI convoy includes an antenna van, electronics van, and a smaller truck. The convoy, driven by its own crew, can cover 500 to 800 km per day. Each system is self-contained, requiring no external power. Currently, observing campaigns last 1 to several weeks, with MV-2 and MV-3 each occupying about two sites per week.

Each of these systems is equipped with the now-standard Mark III VLBI Data Acquisition System featuring computer controlled observing, standard S and X Band receivers for ionospheric calibrations, radiometers for tropospheric water vapor calibration, and environmentally controlled hydrogen maser frequency standards.

The Crustal Dynamics Project observations will concentrate in California and in several other sites west of Colorado. Each summer, MV-2 and MV-3 will be shipped to Alaska for project observations there.

This news item was contributed by Gerald L. Mader, *National Geodetic Survey, NOAA, Rockville, MD 20852.*

Geophysicists

Oliver H. Gish, AGU's oldest and longest-standing member, recently celebrated his 100th birthday. A member of the Geomagnetism and Paleomagnetism section, he joined AGU in 1925.

Richard E. Hallgren, has been appointed assistant administrator for weather services at the National Oceanic and Atmospheric Administration (NOAA). He will continue to serve as Director of NOAA's National Weather Service, a position he has held since 1979. In his 19 years with NOAA Hallgren helped introduce such new technology as automatic weather stations, advanced radar systems, and computerized automation of field operations and services. He helped develop World Weather Watch, an international system that intergrates weather monitoring and forecasting systems, and directed U.S. efforts in the 1979 Global Weather Experiment that assessed the practical limits of weather forecasting.

Stephen R. Mosier, has been appointed associate vice president for international affairs for the University of Houston System. Since 1981 he has served as director of U.S.–French and U.S.–Belgian cooperative programs at the National Science Foundation. Prior to that he was director of U.S.–Japanese programs at the foundation.

Texas A&M University has announced the following promotions of AGU members:

N. L. Carter, from head, Department of Geophysics, to professor of geophysics; ***Gordon P. Eaton,*** from dean of the College of Geosciences to provost and vice president for academic affairs; ***Mel Friedman,*** from associate and interim dean to dean of the College of Geosciences; ***Charles M. Gilbert,*** from professor of geology, VPI, to head, Department of Geology, College of Geosciences; ***Earl Hopkins,*** from professor of geophysics, geography, geology, and petroleum engineering to head, Department of Geophysics; ***William J. Merrell,*** from assistant department head, Department of Oceanography, to associate dean for research and programs, College of Geosciences.

Barney P. Popkin has joined the NUS Corporation as manager of hydrogeologic services. He will manage a team responsible for developing, managing, and implementing waste-management and water-resources projects throughout the U.S.

Gerald J. Wasserburg has been appointed to the newly created John D. MacArthur chair at the California Institute of Technology. The $1.2 million grant awarded to Caltech by the MacArthur Foundation allowed the university president to choose the field, the recipient, and the duration of the chair. Wasserburg, a geophysicist best known for his work on a chronology for the formation of the solar system, was involved in the Apollo program and has specialized in the analyses of interplanetary dust, meteorites, moon rocks, and terrestrial materials. The new appointment will enable Wasserburg to continue research on the applications of thermodynamic methods to geologic systems.

In Memoriam

The following AGU members are recently deceased:

Harry Larson, 88; a member of the Hydrology Section, he joined AGU in 1947.

Elton V. McCollum, 79, died May 15, 1983. A member of the Geodesy Section, he joined AGU in 1940.

M. M. Newman, 74; a member of the Geomagnetism and Paleomagnetism Section, he had been an AGU member since 1950.

Milton E. Schmidt, 74; a member of the Hydrology Section, joined AGU in 1942.

Books

Nor Any Drop To Drink

William Ashworth, Summit Books, New York, vii + 272 pp., 1982. $17.95 hardbound, $6.95 softbound.

Reviewed by Jay H. Lehr

In *Nor Any Drop To Drink* author William Ashworth displays an exceptional grasp of the hydrologic cycle for one trained as a writer rather than as an earth scientist. Especially remarkable for a popular book is the no-nonsense manner in which he handles popular misconceptions about underground water. Authors of similar books generally mollify readers who hold fallacious, mysterious beliefs concerning groundwater flow. Ashworth gets their attention with the proverbial two-by-four between the eyes by declaring such fallacies to be 100% hogwash. He describes the groundwater system in an exceptionally accurate manner using precise analogies which benefit from his literary skill.

To support his assessment of the nation's water problems, Ashworth draws on a respectable knowledge of population migration and growth and their effects on water supply demand. He is equally talented in balancing environmental concerns with economic needs.

The author is also to be complimented for his clear recognition of the water problems of the state of Arizona. He has done an intensive study of the Central Arizona project and its many weaknesses. He points out that the project will be one of the least-cost-efficient water diversions in national history and advances the opinion that it may never be completed due to the rapidly growing recognition of its deficiencies.

In describing Arizona's problems, Ashworth explains that previously poor water appropriation law is partially to blame for the wanton waste that has marred the history of that state. At the same time he applauds Arizona for at long last writing the most comprehensive water management scheme to reach any state legislature in recent decades. In fact, he holds Tucson, Az., to be the most conservationally aware city in America today. Tucson, he says, has made tremendous strides by changing its habits without altering the overall quality of life as affected by water needs.

Ashworth moves from the prairies of Arizona to the populated east, where he shows equal acumen for the intricacies of the water supply system of New York City, which gathers water from watersheds as far as 240 km away to satisfy the thirst of its citizens. The reader is taught that water diversion is not the program of the west alone. In fact, Ashworth tells us, "The rearrangement of drainage patterns is nearly total: sometimes it seems as though no drop of rain can fall anywhere in the country without being waylaid, bound, gagged, shipped off, and spewed out of a faucet several counties away from its original destination."

Ashworth's prime example of water diversion is the state of California, whose aqueducts twist and wind to feed the incredible overdraft that is the result of the crowded cities and agricultural development of southern California. He quotes Wayne Linn, a California limnologist: "Everytime we have to manipulate the water, it's a monument to man's inability to manage it right in the first place."

But Ashworth recognizes that there will be no way out of this dark tunnel as long as there are so many narrowly oriented water utilities whose sole job is to provide power and water at the lowest possible rate with no consideration for environmental consequences of their actions. And so they continue to talk of diverting the Missouri westward through the farmlands of the Ogallala aquifer. They talk of pipelines from Oregon to Arizona transporting Columbia River water southward to Phoenix. They talk of a pipeline along the Gulf of Texas, running from Louisiana to Mexico and, as it goes, sweeping up water to deposit it into the fertile but dry valley of the Rio Grande. They talk of pipelines in the Adirondacks of New York and of converting Long Island Sound into a freshwater lake. And when they really get wound up, they still talk about the North American Water and Power Alliance (NAWAPA) scheme for picking up the North American continent by the north pole and making all of its northern rivers run backward.

We must still fear this terrible NAWAPA project, especially since Congressman James C. Wright, Jr. (D-Tex.), now more than ever a power in the U.S. House of Representatives, wrote a 1964 book entitled *The Coming Water Famine* in which he supported the folly of NAWAPA. We must never relax our vigil, Ashworth tells us, as there will always be people who are willing to promote such absurdities. It is probable that no author has ever more fully recognized or explained the liabilities of our nation's surface water diversions than William Ashworth.

Ashworth is equally astute when it comes to problems of groundwater overdraft. He offers the reader some well-drawn maps describing the nation's major groundwater resources and indicates the relatively small percentage of our lands that suffer serious overdraft. As with everyone who writes on this subject, however, he focuses the most attention on the famous Ogallala Aquifer whose efforts to gain public sympathy have been astonishingly successful, benefiting people who have practiced water inefficiency at its worst.

Ashworth also clearly analyzes the problems of water desalination and skillfully describes the various ways in which one can turn saltwater into freshwater. In each case he cites the vast amount of energy required to make the rarely practical transition. In sum, I have nothing but the very best to say of Ashworth's accurate, sober, and educational recounting of the status of this nation's water supply and water management failures.

I cannot be as sanguine about his perceptions

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tion of its water quality problems. On this subject he follows the lead of many others who place undue emphasis on doom. His overall effort to develop projections for the future of groundwater pollution is perhaps the weakest point of the book; it lacks adequate detail and draws generally unsupportable conclusions. On the subject of acid rain, which he has obviously studied in great detail and describes well, he also chooses to cast excessive gloom. A sentence in point is, "To pollute the rain, therefore, is to commit the ultimate act of pollution. If the rain is dirty, all waters are dirty. As an act of vandalism of the nation's water supply, dumping filth into the rain could not possibly have any peer." This is an overstatement, making acid rain out to be somewhat more the villian than the scientific community is willing to accept.

To his credit, while haranguing U.S. industry for its water pollution crimes, he cleverly puts the lie to the concept that it is our incessant profit motive that creates the problem. He does this by shifting the focus to Russia, supposedly a nonprofit country, which has managed in a few short decades to turn Siberia's mile deep, 300 mile long Lake Baikal into a virtual dead sea.

Ashworth does exhibit a reasonable knowledge of our hazardous waste disposal problems and describes advances that have been made in recent years in legislation and regulation to limit the mistakes of the past. He points out that new regulations that have greatly reduced legal disposal sites may be increasing the dangerous illegal disposal of waste. His review of hazardous waste problems is an acceptable summary for the lay reader though taken largely from anecdotal newspaper accounts. It does not, however, offer the scholarly detail contained in another new book on the subject, *Hazardous Wastes in America*, recently published by the Sierra Club. Ashworth fails considerably in his attempt to tie hazardous waste disposal to well closings and the scary scenario this offers for the future.

Finally, the book is too often fraught with melodrama, which clouds objective, scientific narrative and damages an otherwise excellent text.

The merits of *Nor Any Drop To Drink*'s first 200 pages are considerable—usually providing well supported, well presented, and very educational material. Less can be said for the final 50 pages of the text where the author tries to tie together all the information he has presented into a variety of sociological theories. He summarizes the doomsaying aspects of his book poorly in a brief chapter called *Losing Control* and then follows it with some rather sophomoric instructions to the readers to put plastic jugs in their commodes and aim their lawn sprinklers to hit the grass instead of the sidewalks.

Thus the book ends with a whimper instead of a bang. It is a shame that the author took great pains to educate himself in all aspects of water supply and delivery but did not manage to obtain a grasp of the kinds of water management techniques that could have been articulately described in the book's summary. Still, I strongly recommend the book to readers desiring a brief, reasonably accurate snapshot of the nation's water supply picture as it comes from the camera today.

Jay H. Lehr is executive director of the National Well Water Association, 500 West Wilson Bridge Road, Worthington, OH 43085.

Random Fields: Analysis and Synthesis

E. Vanmarcke, MIT Press, Cambridge, Mass., xiv + 382 pp., $45.

Reviewed by David J. Thomson

Random Fields is a book which I found both technically interesting and a pleasure to read. The problems considered are those of describing multidimensional stochastic data (as opposed to unidimensional, e.g., multivariate, time series data).

The presentation is clear and the book should be useful to almost anyone who uses random processes to solve problems in engineering or science. The author's approach is informal and, while not careless, is not intended for mathematical purists. For example, the index contains six references to limited resolution of measurements but none to measure theory.

The areas covered reflect the author's interest and expertise. I was particularly impressed by the introduction: The emphasis on utility and the importance of local averages is reminiscent of Slepian's classic paper "On Bandwidth" (*Proceedings of the IEEE, 64*, 292–300, 1976); it is also refreshing to read a work on stochastic processes where the author emphasizes that microscopic variations may be of no practical interest to the problem at hand!

Both chapter 2, which provides general background on random fields, and chapter 3, which summarizes second order theory, are well written. Chapter 4, "Spectral Parameters, Level Excursions and Extremes," is an unusually clear and orderly treatment of these topics, although, for example, Rainal's contribution (*Bell System Technical Journal, 47*, 2239–2258, 1968) to this area is not described. Chapters 5–7 cover one-, two-, and multidimensional local average processes. In these the emphasis is again on descriptive statistics such as level crossing rates and extremes parameterized by covariance and spectral functions. A number of interesting constraints imposed on the spectra by the multidimensionality are described; however, the omission of the Paley-Wiener conditions is unfortunate. The section of chapter 8 on parameter estimation is dated and is perhaps the least satisfactory part of the book.

While the chapters present a continuity of thought, the book is well indexed and, for the most part, can be read in sections. The book contains no end-of-chapter problems and so is better suited for study at the postgraduate level than as classroom text. Also, there are no "extended" examples, so those seeking simple solutions to complex problems may be disappointed. There is, on the other hand, much which will guide one toward a useful solution. Compensating for the lack of "extended" examples are many "tiny" examples and continued emphasis on describing the mathematics in physical terms.

David J. Thomson is with Bell Laboratories, Whippany, NJ 07981.

New Publications

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Absorption and Scattering of Light by Small Particles, C. F. Bohren and D. R. Huffman, John Wiley, New York, xiii + 530 pp., 1983, $44.95.

Exploration Seismology, vol. 1, *History, Theory, and Data Acquisition*, R. E. Sheriff and L. P. Geldart, Cambridge University Press, New York, xii + 253 pp., 1983, $44.95.

From Rift to Drift: Iowa's Story in Stone, J. C. Troeger, Iowa State University Press, x + 152 pp., 1983, $14.95.

Geodetic Monitoring of Tectonic Deformation: Toward a Strategy, Panel on Crustal Movement Measurements, Committee on Geodesy/Committee on Seismology, Assembly of Mathematical and Physical Sciences, National Research Council, National Academy Press, Washington, D. C., x + 109 pp., 1981.

Introduction to Plasma Theory, D. R. Nicholson, John Wiley, New York, xii + 292 pp., 1983, $29.95.

Polarographic Oxygen Sensors: Aquatic and Physiological Applications, E. Gnaiger and H. Forstner (Eds.), Springer-Verlag, New York, viii + 370 pp., 1983.

Proceedings of the Seventh Symposium on Antarctic Meteorites, vol. 25, *Mem. of Nat. Instit. of Polar Res. Spec. Issue*, T. Nagata (Ed.), National Institute of Polar Research, Tokyo, + 343 pp., 1982.

Seafloor Referenced Positioning: Needs and Opportunities, Panel on Ocean Bottom Positioning, Committee on Geodesy, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, National Academy Press, Washington, D.C. viii + 53 pp., 1983.

Short Period Climatic Variations, vols. 1 and 2, J. Namias, University of California, San Diego, California, v + 393 pp., 1982, $13.50.

Weather in Your Life, L. J. Battan, W. H. Freeman, San Francisco, x + 230 pp., 1983, $19.95 (hardbound), $10.95 (paper).

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For further information, call toll free 800-424-2488 or, in the Washington, D. C., area, 462-6903.

POSITIONS AVAILABLE

Rensselaer Polytechnic Institute/A Tenure-Track Faculty Position and a Post-Doctoral Research Position. The Department of Geology of Rensselaer Polytechnic Institute is seeking applicants for two openings, a tenure-track faculty position and a postdoctoral research position.

The faculty position available in September 1984 requires a Ph.D. or equivalent degree. The area of specialization within the geosciences is open. Particularly important is the applicant's interest in research and teaching at both the undergraduate and graduate levels (M.S. and Ph.D.) with capability to do creative research in the quantitative sciences. Preference will be given to individuals with research experience beyond the Ph.D.; the level of the appointment is open.

The postdoctoral position is available beginning January 1984 to do research in the field of fission track analysis applied to studies of sedimentary basins. Applicants must be knowledgeable and experienced in fission track analysis.

Our present department is part of a modern, technologically-oriented university, and consists of seven members whose collective expertise encompasses structural geology, geophysics, geochemistry, petrology, glacial and surficial geology, and ecological modeling. The RPI environment provides ample opportunities for field and laboratory experimental research in geology, as well as for interdisciplinary studies in chemistry, physics, biology, mathematics, materials science, engineering and computer science.

A resume and the names of three persons who would be willing to provide letters of reference should be sent to: Donald S. Miller, Chairman, Department of Geology, Rensselaer Polytechnic Institute, Troy, NY 12181.

Rensselaer is an Equal Opportunity/Affirmative Action Employer.

University of Minnesota Stratigrapher/Sedimentary Petrologist. Tenure-track position starting Fall 1984, probably at the Assistant Professor level. The candidate must have a Ph.D. with interest in stratigraphy of sedimentary basins, tectonics and sedimentation, and sedimentary petrology, and will be expected to carry out research and to teach graduate and undergraduate courses in these fields. Please submit resume, academic records, and three letters of recommendation to Dr. Peter J. Hudleston, Department of Geology and Geophysics, 108 Pillsbury Hall, University of Minnesota, Minneapolis, MN 55455 (612)376-8373.

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Postdoctoral Research Associate Positions/Johns Hopkins University. Positions are available for studies of planetary magnetospheres, and ion studies of earth magnetospheric and auroral physics, as well as in a newly initiated program in solar physics. Selected candidates will participate in the analysis and interpretation of data obtained from deep space probes (Voyager), or particle field, and solar or atmospheric emissions data from earth orbiting spacecraft. Positions are one year, renewable opportunities with flexible starting dates. Contact: Neil Avill, Department LER-320E The Johns Hopkins University Applied Physics Laboratory, Johns Hopkins Road, Laurel, Maryland 20707.

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Faculty Position Available/Massachusetts Institute of Technology. The Department of Earth, Atmospheric, and Planetary Sciences at M.I.T. is seeking to fill a faculty position in seismology. Applicants should preferably have an interest and ability in theoretical seismology, and would be expected to supervise graduate students and teach courses at the undergraduate and graduate level as well as conduct research in that field. Rank is open and depends upon qualifications.

Applicants should send their vitae, list of publications, and a statement of research and teaching interests, no later than 1 November 1983 to:

Prof. W. F. Brace, Chairman
Department of Earth, Atmospheric, and Planetary Sciences
54-918, M.I.T.
Cambridge, MA 02139

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THE UNIVERSITY OF SHEFFIELD
DEPARTMENT OF APPLIED AND COMPUTATIONAL MATHEMATICS

RESEARCH ASSISTANT FOR COMPUTATIONAL ANALYSIS OF EISCAT HIGH-LATITUDE RADAR DATA

Applications are invited for the above SERC-supported post for the analysis and interpretation of EISCAT radar data on the high-latitude ionosphere and magnetosphere. The work will require examination of the radar spectra obtained from EISCAT experiments and development of computer programs to analyse the spectra. Visits to the EISCAT sites in northern Scandinavia may be required. Candidates should hold a PhD (or equivalent qualification) in applied mathematics or physics. Tenable for 3 years. Initial salary £7,190–£7,630 a year on Range IA. **Applications, including curriculum vitae and naming 2 referees, should be sent as soon as possible to Dr. R. J. Moffett, Department of Applied and Computational Mathematics, the University, Sheffield S10 2TN, United Kingdom. Quote ref: R894/HZ.**

Professor of Marine Geophysics Tectonics/Stanford University. The Department of Geophysics, Stanford University, is seeking candidates for a tenure track position in the broad area of marine geophysics and tectonics. We seek a creative scientist with experience in gathering, interpreting, and synthesizing marine geophysical data and whose research interests cover depositional, igneous, and tectonic processes on oceanic plates and continental margins. Inquiries are invited from marine geophysicists with demonstrated scientific record in one of the above aspects of marine geophysics or tectonics, who have demonstrated an ability to develop new ideas and research directions, and to guide and teach graduate and undergraduate students. In considering this appointment we are interested in maximizing interaction with ongoing research groups in marine geology, plate tectonics, paleomagnetism, seismology and regional geology at Stanford. Our new faculty member will be expected to develop a strong research program involving both government and industrial participation.

Salary and rank will be commensurate with experience and background. Please submit a resume, a brief description of teaching and research interests, and references to:

Dr. Amos Nur
Department of Geophysics
321 Mitchell Building
Stanford University
Stanford, CA 94305

Stanford University is an equal opportunity employer, and encourages the application of qualified women and minorities.

Tenure-Track Faculty Position-Geophysics/New Mexico State University. We are seeking a faculty member whose duties will include teaching both undergraduate and graduate level courses, conducting research and supervising graduate level thesis and dissertation research. We are particularly interested in a seismologist, but persons with experience in other geophysical techniques are invited to apply.

Minimum qualifications include an earned doctorate in geophysics or a closely related area and demonstrated research capability. Teaching experience and demonstrated ability to secure research funding are desirable. The position is available in January 1984 for 9-month academic year. Appointment will be at the rank of Assistant or Associate Professor. Salary and academic rank will be dependent on experience and qualifications.

Applications and names, addresses and telephone numbers of at least three references should be submitted to Dr. Chandler Swanberg, Department of Earth Sciences, P.O. Box 3AB, Las Cruces, NM 88003.

Applications received by October 15, 1983 will be given preference.

New Mexico State University is an Affirmative Action/Equal Opportunity Employer.

Chairman-Department of Geological Sciences/Wright State University. The Department of Geological Sciences invites applications for the position of chairman to be appointed September 1984. We seek a dynamic individual with administrative talent and an appropriate mix of research and practice-related educational activities. Rank is at the full professor level and no restrictions have been placed on areas of specialization. The department is active with 12 faculty and an emphasis on professional practice, yet maintaining a firm commitment to basic research.

Send a letter of application, curriculum vitae and names of three references to:

Chairman, Search Committee
Department of Geological Sciences
Wright State University
Dayton, OH 45435

Wright State University is an affirmative action/equal opportunity employer. Closing date for the position is October 31, 1983.

Earth Sciences

The Lamont-Doherty Geological Observatory of Columbia University invites scientists interested in any field of the earth sciences to apply for the following fellowships: Two postdoctoral fellowships, each awarded for a period of one year (extendable to two years in special instances) beginning in September, 1984 with a stipend of $25,000 per annum.

Completed applications are to be returned by January 15, 1984. Application forms may be obtained by writing to the Director, Lamont-Doherty Geological Observatory, Palisades, New York 10964. Award announcements will be made February 28, 1984, or shortly thereafter.

Columbia University is an Affirmative Action/Equal Opportunity Employer.

Research Associate/Petrography-Petrology. To join a research effort aimed at understanding the condensation history of the solar system by mineralogical, chemical, and isotopic studies of tiny inclusions in primitive meteorites. Applicant need not have previous experience with meteorites but should be a superb petrographer, skilled in the use of the SEM and electron probe. Successful candidate will be dedicated, productive, an effective communicator both orally and in writing, and will have Ph.D. in hand. Vacancy expected in mid autumn 1983.

Send resume and names of three references to I. Grossman, Department of the Geophysical Sciences, University of Chicago, 5734 S. Ellis Avenue, Chicago, IL 60637.

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Candidates should possess a Ph.D. or equivalent experience in oceanographic, coastal or meteorological sciences, which has provided a broad and comprehensive knowledge of environmental sciences with emphasis on chemical, biological or physical oceanography and/or meteorology. Considerable experience in administration and management of research and its application to development is necessary.

Interested persons should submit a resume or Standard Form 171, Personal Qualifications Statement (available at Federal Job Information Centers or from the address below), to:

OFFICE OF NAVAL RESEARCH
Civilian Personnel Division, Code 791SC • ATTN: Announcement #83–15–A (EOS)
800 North Quincy Street • Arlington, VA 22217

The date for accepting applications has been extended through 31 October 1983 and they must be received by that date. For further information and supplemental forms, please call (202) 696-4705.
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The University of Missouri-Columbia/Faculty Positions. The University of Missouri-Columbia Department of Geology plans immediate expansion through the addition of three tenure-track faculty positions. Appointments are anticipated at the assistant professor level, although higher ranks may be possible, beginning in August of 1984. Candidates will be expected to have completed requirements for the Ph.D. degree by that time. Faculty members are required to provide quality instruction at both undergraduate and graduate level, and conduct research leading to scholarly publications. Successful candidates will be chosen from the following specialties:

Exploration Geophysics
Solid-Earth Geophysics
Hydrogeology
Analytical Structural Geology
Clastic Sedimentology

Applications should send resume, transcripts, and names and addresses of three references to:

Tom Freeman, Chairman
Department of Geology
University of Missouri
Columbia, MO 65211

GROUNDWATER HYDROLOGIST Opening for a staff or project level groundwater hydrologist to play a lead role in our rapidly expanding geohydrology group. Minimum requirements include a BS or MS degree in Civil/Environmental Engineering or Hydrology with 3–5 years' related experience in groundwater modeling, computer applications and project management. The successful candidate will have demonstrated mathematical simulation skills, hands-on computer modeling and graphic experience, (FORTRAN, CSMP codes, etc.) and application of these tools in the assessment of hazardous waste sites and processes. Project responsibilities will require knowledge of current state-of-the-art technology related to groundwater flow and mass transport in saturated/unsaturated porous and fractured media, and the physical, chemical and biological processes associated with these phenomena. Verbal and written communication skills as well as proven experience working with and directing the efforts of multidisciplinary project teams are essential.

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FACULTY POSITION IN GEOLOGY/UNIVERSITY OF PUGET SOUND Tenure-track Assistant Professor. Field-oriented Geomorphologist with strong interest in Quaternary glacial stratigraphy and landscape processes to begin February 1, 1984 or September 1, 1984; salary commensurate with experience. The department (5 career faculty) has long established, successful undergraduate program with joint faculty/student research. Team teach Physical Geology—Topics, (all three faculty teach both lecture and labs) and teach a senior level Geomorphology course (lecture and lab) with a process and quantitative focus, including computer applications (Fall). Teach Physical Geology (lecture and lab) and share teaching responsibilities in Historical Geology (Spring). Participate in departmental/University governance, advise students, and continue professional development. Ph.D. in Geology, ability to teach both majors and non-majors, and ability to carry out cooperative, interdisciplinary research with undergraduate geology and other science majors. (Additional info available at Indianapolis GSA meetings). Submit detailed vita, statement of short- and long- term career objectives, transcripts, and names of three references by November 10, 1983, to: Geology Search, University of Puget Sound, P.O. Box 7297, Tacoma, WA 98407. An Equal Opportunity, Affirmative Action Educator/Employer.

Iowa State University of Science and Technology, Department of Earth Sciences. Applications are invited for a tenure track faculty position in Meteorology. Rank is at the assistant or associate professor level, dependent upon qualifications. The successful applicant will be expected to develop a strong research and graduate student program and will teach undergraduate and graduate courses for meteorology majors.

The position is for a person with proven expertise within the general area of dynamic meteorology. Teaching will involve an undergraduate course in synoptic meteorology, in addition to courses related to the field of expertise. Completion of the Ph.D. prior to appointment is strongly preferred. In addition, research ability shown by other publications and/or postdoctoral experience will be an advantage.

Iowa State offers degrees in meteorology through the Ph.D. The program includes about 60 undergraduate majors; the graduate/research program is strong and emphasizes theoretical, dynamic studies. Close relationships are established with the facilities and personnel of major national laboratories. New campus facilities for meteorology are currently under construction.

The appointment is expected to begin no later than September, 1984; an appointment during the current academic year may be possible. Application deadline is November 1, 1983; later applications will be accepted if the position is not filled. For application information please write to:

Dr. Bert E. Nordlie
Department of Earth Sciences
Iowa State University
253 Science I
Ames, Iowa 50011

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RESEARCH OPPORTUNITIES

Competitive visiting scholar awards for one or two years' tenure in selected federal laboratories throughout the United States. Opportunities are available for specialized experimental or theoretical research experience—free of interruptions and distractions of other duties—in the general fields of:

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Most of the 19 programs are open to U.S. and non-U.S. nationals, and most are open to experienced senior investigators as well as to recent PhDs.

Application materials with details on research opportunities and laboratory locations may be requested by letter, stating the specific area of research interest, to:

Associateship Programs
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NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue
Washington, D.C. 20418

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Meteorologist/The City College of The City University of New York. The Department of Earth and Planetary Sciences invites applications for an anticipated opening in meteorology. The appointment will start September, 1984. Applicants should have completed the Ph.D. by the time of appointment and have a strong background in synoptic meteorology and computer applications. In addition, the individual should have an interest in atmospheric chemistry or pollution as applied to urban areas, or physical oceanography. The person hired will be required to teach courses in meteorology, and possibly physical oceanography as well as develop and maintain an active research program. Participation in the C.U.N.Y. Ph.D. Program in Earth and Environmental Sciences is anticipated. Rank and salary will be commensurate with experience. Send resume, transcripts and three letters of reference by November 30, 1983 to Professor Dennis Wess, Chairman, Department of Earth and Planetary Sciences, the City College, 138 Street and Convent Avenue, New York, N.Y. 10031.

The City College of the City University of New York is an equal opportunity affirmative action employer.

Groundwater Hydrologist/Jordan Gorrill Associates. The Geotechnical and earth science subsidiary of E.C. Jordan Co., Portland, Maine, has an opening for a senior groundwater hydrologist. Candidates should have an advanced degree in hydrogeology or geotechnical engineering and a minimum of seven years of professional experience. Capabilities and experience in field studies and computer modeling of groundwater flow and solute transport is essential. Client contact experience and good writing skills, including report writing experience, are highly desirable. Position will involve work on solid and hazardous waste projects.

Jordan Gorrill Associates is a nationally recognized geotechnical consulting firm providing a wide range of services in geotechnical engineering, geology, hydrogeology, geophysics, and soil science.

Send resume to: Director of Personnel, Jordan Gorrill Associates, subsidiary of E.C. Jordan Co., 502 Congress St./P.O. Box 7050, Portland, ME 04112. (207) 775-2928.

E.C. Jordan Co. is an Equal Opportunity Employer, M/F.

Geophysicist. New Mexico Institute of Mining and Technology invites applications for a tenure track position in explorations seismology at the assistant professor level to begin as soon as possible. The position will be a joint appointment between the College Division and the Research and Development Division. A PhD is required. Send letter of application, resume, brief description of teaching and research interest and names of three references to: Personnel, Brown Hall 17, New Mexico Institute of Mining and Technology, Socorro, NM 87801.

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SERVICES, SUPPLIES, COURSES AND ANNOUNCEMENTS

The University of California at Berkeley/Space Sciences Laboratory Senior Fellow Program. Renewable three-year appointments will be awarded to Ph.D. scientists who have demonstrated leadership and creativity in astrophysics or space science. Fellows will receive Principal Investigator status and will be expected to develop their own research groups and participate in educational activities of the academic departments. The level, to be determined at the time of appointment, will be Assistant, Associate, or Full Research Scientist depending upon qualifications.

Vita, bibliography, statement of prospective research program and three letters of reference should be sent by December 1, 1983 to Christopher McKee, Acting Director, Space Sciences Laboratory, University of California, Berkeley, California 94720.

The University is an Affirmative Action/Equal Opportunity Employer.

AGU Congressional Science Fellowship. Individuals who are AGU members and U.S. residents are invited to apply for a 1-year assignment on the staff of a congressional committee or a House or Senate member as an advisor on a wide range of scientific issues affecting public policy questions.

Applicants should have a broad background in science, be articulate, literate, and flexible; and be able to work well with people from diverse professional backgrounds.

A public policy background is not required, although such experience and/or a demonstrable interest in applying science to the solution of public problems is desirable.

The fellowship carries with it a stipend of up to $29,000 plus travel allowances.

How to apply:

Applicants should submit a letter of intent, a curriculum vitae, and three letters of recommendation. The letter of intent should include a statement of why the fellowship is desired, how you qualify for it, what issues and congressional situations interest you, what role you envision as a congressional science fellow, and what outcome you hope for in relation to career goals. The individuals from whom you request letters of recommendation should discuss your professional competence and other aspects of your background that make you particularly qualified to serve as a Congressional Science Fellow.

Send your application to: Department MP, Congressional Science Fellowship, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Application Deadline: March 31, 1984

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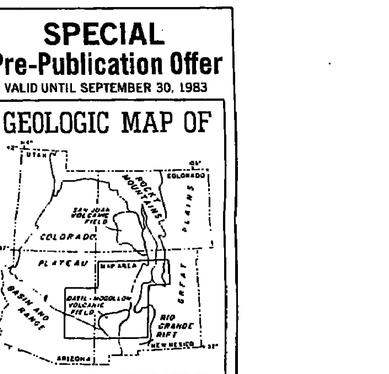

THE RIO GRANDE RIFT AND SOUTHEASTERN COLORADO PLATEAU, NEW MEXICO, AND ARIZONA—1983
by W. S. Baldridge, Y. Bartov, and A. Kron

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Meetings

Announcements

Geological Congress Update

The deadline for declaring an intention to attend the 1984 International Geological Congress (IGC) has been extended to September 30, 1983. The meeting, sponsored by the USSR National Committee for Geology, International Union of Geological Sciences (IUGS), will be held in Moscow, USSR, August 4–14, 1984.

For additional information, contact the Organizing Committee of the 27th IGC, Institute of the Lithosphere, 22, Staromonetny, Moscow, 109180.

Cometary Astronomy

The 1983 American Workshop on Cometary Astronomy will be held October 1, 1983, in Pasadena, Calif. The workshop will include presentations by John Bortle, Charles Morris, Ray Newburn, John Sanford, Zdenek Sekanina, Paul Weissman and others. Tours of the Jet Propulsion Laboratory's Space Flight Operations Facility and sessions in the San Gabriel Mountains on observational techniques are also on the agenda. This second annual workshop is being sponsored by the International Halley Watch and *International Comet Quarterly*.

Attendance is limited to the first 100 registrants. Non-U.S. citizens need security clearances. For more information contact Comet Workshop, Jet Propulsion Laboratory, M/S T-1166W, 4800 Oak Grove Drive, Pasadena, CA 91109.

Rock Mechanics

The 25th U.S. Symposium on Rock Mechanics will be held June 25–27, 1984, in Evanston, Ill. The organizers of the symposium are soliciting papers on the following topics: in situ stress (types and measurement), design analysis, deformation behavior, foundations behavior, fracture (lab and field), site characterization, variations in liner design, design of protective structures, improvements in blasting techniques, waste isolation in repository design and construction, earthquake source mechanisms, machine-rock interaction, and ground control in mining.

Authors should submit abstracts of up to 1000 words and several figures by November 1, 1983, to C. H. Dowding, Department of Civil Engineering (25), Northwestern University, Evanston, IL 60201 (telephone: 312-492-7270).

Pacific Chemical Congress

The 1984 International Chemical Congress of Pacific Basin Societies (PAC CHEM '84), the first chemical conference ever held for the entire Pacific Basin, will take place December 16–21 in Honolulu, Hawaii. The conference program consists of more than 60 symposia with papers being presented on recent developments in agrochemistry; analytical, clinical, environmental, and health chemistry; applied chemistry; biological and pharmaceutical chemistry; catalysis, colloidal, physical, and surface chemistry; economics and management; geochemistry; inorganic and nuclear chemistry; information transfer and computation; macromolecular chemistry; and organic chemistry. Speakers at the plenary sessions will deal with such topics as energy, food, economic development, population stabilization, and the role of chemistry in enhancing the development of the Pacific Basin.

In order to have a paper considered for presentation at the conference, five copies of a 150-word abstract (with the original on a special PAC CHEM form for reproduction) and one copy of an expanded 500-1000 word abstract must be submitted by June 1, 1984, to PAC CHEM '84, Meetings and Divisional Activities Department, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, DC 20036 (telephone: 202-872-4396) or to PAC CHEM '84, The Chemical Institute of Canada, 151 Slater Street, Suite 906, Ottawa, Ontario K1P 5H3 (telephone: 613-233-5623) or to PAC CHEM '84, The Chemical Society of Japan, 1–5, Kanda-Surugadai, Chiyoda-ku, Tokyo 101 (telephone: 03–292–6161). Persons in all other countries may contact the International Activities Office of the American Chemical Society for more information (telephone: 202-872-4449; cable: JIECHEM; telex: 892582). The official language of the conference is English.

The Pacific Chemical Congress Subcommittee on Scientific Program Development will referee all contributed papers, and notifications will be sent to authors by July 15, 1984. Contributed papers will be considered for appropriate symposia, for general sessions, and for poster presentations.

The conference is sponsored by the chemical societies of Canada, Japan, and the United States and chemical societies from Asia, Latin America, and 16 other Pacific Basin countries will participate officially in the congress.

Geophysical Year

The complete Geophysical Year last appeared in the August 30, 1983, *Eos*.

New Listings

A boldface meeting title indicates sponsorship or cosponsorship by AGU.

June 25–27, 1984 25th U.S. Symposium on Rock Mechanics, Evanston, Ill. (C. H. Dowding, Dept. of Civil Engineering (25), Northwestern Univ., Evanston, IL 60201; tel.: 312-492-7270.)

Sept. 24–25, 1984 Seminar: Enhanced Biological Removal of Phosphorus from Wastewater, Paris, France. Sponsor, International Association on Water Pollution Research and Control. (Michel Florentz, Phosphorus Seminar, Anjou-Recherche, 52, rue d'Anjou, 75384 Paris Cedex 08, France; tel.: 266–91–50; telex: Geneaux 280 332 F.)

Dec. 16–21, 1984 International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii. Sponsors, ACS, Chemical Institute of Canada, and Chemical Society of Japan. (PAC CHEM '84, Meetings and Divisional Activities Dept., American Chemical Society, 1155 Sixteenth St., N.W., Washington, DC 20036; tel.: 202-872-4396; PAC CHEM '84, The Chemical Institute of Canada, 151 Slater St., Suite 906, Ottawa, Ontario K1P 5H3; tel.: 613-233-5623; PAC CHEM '84, The Chemical Society of Japan, 1–5, Kanda-Surugadai, Chiyoda-ku, Tokyo 101; tel.: 03–292–6161.)

AGU Fall Meeting: Housing and Registration

The 1983 Fall Meeting of the American Geophysical Union will be held in San Francisco, California, December 5–10 at the Cathedral Hill Hotel and the Holiday Inn Golden Gateway Hotel. San Francisco is a dynamic, exciting city, known to the world for its spectacular scenery, fabulous restaurants, cosmopolitan life style, and gentle climate. It is a superb meeting location at any time of the year.

Registration

Everyone who attends the meeting must register. Preregistration (received by November 10) saves you time and money. The fee will be refunded to you if AGU receives written notice of cancelation by November 28. Registration rates are as follows:

	Preregistration	After Nov. 10
Member	$65	$80
Student member	$32	$47
Retired senior member	$32	$47
Nonmember	$90	$105
Student nonmember	$41.50	$56.50

Registration for 1 day only is available at one half the above rates, either in advance or at the meeting. Members of the American Meteorological Society, the American Society of Photogrammetry, the European Geophysical Union, Unión Geofísica Mexicana, and the American Congress on Surveying and Mapping may register at the AGU member rates.

The difference between member (or student member) registration and nonmember registration may be applied to AGU membership dues if a completed membership application is received at AGU by February 10, 1984.

To preregister, fill out the registration form, and return it with your payment to AGU by November 10. Your receipt will be included with your preregistration material at the meeting. Preregistrants should pick up their registration material at the registration desk at the Cathedral Hill Hotel. Hours are 8 A.M. to 4 P.M., Monday through Saturday. On Sunday, December 4, registration hours are 5:30 to 7:30 P.M.

Hotel Accommodations

Blocks of rooms ($47 singles, $53 doubles) are being held at the Cathedral Hill, the Holiday Inn Golden Gateway, the Holiday Inn Civic Center, the San Francisco, and the Grosvenor Inn for those attending. Read the housing application, and mail the completed application form to the housing bureau each to ensure reservations at your preferred hotel. ***Reservation forms must be sent directly to the Housing Coordinator, AGU Fall Meeting, San Francisco Housing Bureau, P.O. Box 5612, San Francisco, CA 94101.*** Do not send housing reservation forms to the hotels.

Reservations must be received by November 1 to be confirmed. Do not write or call AGU for room reservations.

Free parking is available only to registered guests of each hotel as indicated.

Scientific Sessions

The program summary will be published in the October 18 *Eos*. The preliminary program along with the abstracts will be published in the November 8 *Eos*. The final program, with presentation times, will be distributed at the meeting. Scientific sessions will be held at the Cathedral Hill and the Holiday Inn Golden Gateway hotels only.

New Special Sessions

See the June 28, July 26, and August 16 issues of *Eos* for listings of other special sessions

Geodesy (G)

Lasar Geodynamics Satellites (LAGEOS) (Session chairman: S. C. Cohen, NASA/GSFC, tel. 301-344-8555)

Crustal Dynamics (Session chairman: Don Trask, JPL, tel. 213-354-4878)

Global Positioning Satellite: Geodetic and Geophysical Applications (Session chairman: M. Ananda, Aerospace Corporation, tel. 213-647-1947)

Interdisciplinary Research in Geodesy and Oceanography (cosponsored with Ocean Sciences (*O*) (Session chairman: C. J. Koblinsky, NASA/GSFC, tel. 301-344-7026)

Session Highlights

See the June 28, July 26, and August 16 issues of *Eos* for descriptions of other special sessions.

Interdisciplinary Research in Geodesy and Oceanography (G & O)

Progress on a variety of interdisciplinary problems in geodesy and oceanography has been achieved recently as a result of the great improvements in satellite positioning. Such problems include: tides; the geopotential and gravity fields; ocean bathymetry; seafloor spreading; ocean circulation; and the effects of the ocean on the rotation of the earth. Invited talks by leaders in the field will summarize current trends and future directions of interdisciplinary work in geodesy and oceanography, as well as describe upcoming satellite missions affecting this research.

There will also be two additional sessions to incorporate timing, earth rotation, tides, and gravity data analysis.

Exhibits

The exhibits will be located on the mezzanine, Cathedral Hill Hotel, Monday through Thursday, December 5–8, 9:30 A.M. to 4:00 P.M.

The following exhibitors are confirmed:

Academic Press, Inc.
American Geophysical Union
Defense Mapping Agency/HTC
EG&G Geometrics
Elsevier Science Publishing Co.
Hamlar
Jet Propulsion Laboratory
Kinemetrics
Nature's Own
Phoenix Geophysics
Qualimetrics, Inc.–WEATHERtronics
Refraction Technology
Schonstedt Instrument Co.
Sprengnether Instruments
Springer-Verlag, New York
Teledyne Geotech

Meetings *(cont. on p. 554)*

FIELD TRIP FORM

I wish to attend the Franciscan Nano-terrane field trip on Sunday, December 4. My check for $25 is enclosed.

In case I am not among the first 40:

☐ I wish to be put on the waiting list. (If you don't go, money will be returned on the day of the trip.)

☐ I wish my money returned.

Signature _____ Print Name _____

Date _____

Address _____

_____

Telephone _____

Mail form to: M. C. Blake, Jr., Mail Stop 75, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

RETURN THIS FORM WITH PAYMENT TO:

Meeting Registration
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

PLEASE PRINT CLEARLY

NAME ON BADGE _____

AFFILIATION _____

MAILING ADDRESS _____

_____

_____

TELEPHONE # _____

HOTEL

_____

Days you plan to attend
Please check the appropriate box(es)
☐ Dec. 5 ☐ Dec. 6 ☐ Dec. 7
☐ Dec. 8 ☐ Dec. 9 ☐ Dec. 10

Members of the cooperating societies may register at AGU member rates
Please check appropriate box
☐ Member AGU ☐ Nonmember
Member cooperating society:
☐ AMS-American Meteorological Society
☐ ASP-American Society of Photogrammetry
☐ ACSM-American Congress on Surveying and Mapping
☐ EGU-European Geophysical Union
☐ UGM-Unión Geofísica Mexicana

Nonmembers

The difference between member (or student member) registration and nonmember registration may be applied to AGU dues if a completed membership application is received at AGU by February 10, 1984.

Preregistrants

Your receipt will be in your preregistration packet. The registration fee will be refunded if written notice of cancelation is received in the AGU office by November 28. The program and meeting abstracts will appear in the November 8 issue of *Eos*.

AGU 1983 FALL MEETING
DECEMBER 5-10
San Francisco, California

REGISTRATION FORM

Deadline for Receipt of Preregistration NOVEMBER 10, 1983

(rates applicable only if received by November 10 with payment)

	More than one day	One day
MEMBER	☐ $65	☐ $32.50
STUDENT MEMBER	☐ $32	☐ $16
RETIRED SENIOR MEMBER*	☐ $32	☐ $16
NONMEMBER	☐ $90	☐ $45
STUDENT NONMEMBER	☐ $41.50	☐ $20.75

*65 or over

SECTION LUNCHEONS/DINNER

Circle section and indicate number of tickets. All lunches begin at noon. SPR dinner begins at 6:30 P.M.

____ Planetology/Volcanology, Geochemistry and Petrology, Tuesday, $9
____ Seismology/Tectonophysics, Tuesday, $5
____ Geomagnetism and Paleomagnetism, Wednesday, $5
____ Hydrology, Wednesday, $9
____ Ocean Sciences, Wednesday, $9
____ Solar-Planetary Relationships, Wednesday, $20 (dinner)
____ Atmospheric Sciences, Thursday, $9
____ Geodesy, Thursday, $9

Total Enclosed $ _____
(All orders must be accompanied by payment or credit card information. Make check payable to AGU.)

Charge to: ☐ American Express ☐ Visa ☐ Master Card

Card Number _____

Master Card Interbank No. _____

Expiration Date _____

Signature _____

Office Use
Code
Check No.

HOTEL ACCOMMODATIONS

PARTICIPATING HOTELS

Cathedral Hill Hotel
Van Ness at Geary Street
(800) 227-4730

Holiday Inn Golden Gateway
1500 Van Ness Avenue
(415) 441-4000

Grosvenor Inn
Van Ness and Geary
(415) 673-7411

Holiday Inn Civic Center
50 8th Street
(415) 626-6103

San Franciscan Hotel
1231 Market Street
(415) 626-8000

ROOM RATES FOR ALL HOTELS

Single $47
Double $53
Twin $53

Suites available upon request

PARKING: **Cathedral Hill Hotel:** free to registered guest
Holiday Inn Golden Gateway: free to registered guest
San Franciscan Hotel: free to registered guest

All hotel reservations must be made on the housing form by November 1, 1983. No telephone requests will be accepted. Confirmations will be mailed directly to registrants by the individual hotels. After confirmation has been received, changes and cancelations should be made directly to the hotel.

Mail your completed form directly to:

Housing Coordinator
AGU Fall Meeting
San Francisco Housing Bureau
P.O. Box 5612
San Francisco, CA 94101

American Geophysical Union
1983 FALL MEETING

HOUSING REGISTRATION FORM

READ CAREFULLY and RETURN FORM DIRECTLY TO THE SAN FRANCISCO HOUSING BUREAU AT THE FOLLOWING ADDRESS:

Housing Coordinator
AGU Fall Meeting
SF Housing Bureau
P.O. Box 5612
San Francisco, CA 94101

Please print or type all information, abbreviating as necessary. Confirmation will be sent by the hotel to the individual named in Part I. If more than one room is required, this form may be photocopied.

Part I

REQUESTED BY
Last Name _____ First _____
Name of Company or Firm _____
Street Address or P.O. Box Number _____
City _____ State/Prov. _____ Zip-U.S.A. _____
Country _____ Telephone Number _____

Part II

INSTRUCTIONS: Select *THREE* hotels of your choice from the list of participating facilities, then enter the name on the lines below.

First Choice _____ Second Choice _____ Third Choice _____

NOTE: Rooms are assigned on a "First Come, First Served" order, and if none of your choices is available, another facility will be assigned based on a referral system. A cut-off date is in effect; your application may not be processed if received after 14 days prior to your arrival date. **AGU housing registration deadline is November 1.**

Part III

INSTRUCTIONS: 1. Select type of room desired with arrival and departure dates.
2. *PRINT* or *TYPE* names of *ALL* persons occupying room.
3. If more than two persons share a room, check twin and the hotel will assign two double beds.

CHECK ONE		Guest Names (Last name first)
☐ SINGLE (Room with one bed one person)	Arrival Date _____	1. _____
☐ DOUBLE (Room with one bed two persons)	Arrival Time _____ AM/PM	2. _____
☐ TWIN (Room with two beds two persons)	Departure Time _____	3. _____
☐ EXTRA PERSON		4. _____

IMPORTANT NOTE: Hotel MAY require a deposit or some other form of guaranteed arrival. If so, instructions will be on your confirmation form.

Meetings (cont. from p. 553)

Social Events

An icebreaker party on Monday evening at the Cathedral Hill Hotel will be the opening social event of the meeting. There will be an awards ceremony on Thursday evening from 5:45 to 6:30 P.M. in the Crystal Ballroom of the Holiday Inn Golden Gateway. All meeting participants are invited to attend. At a wine-tasting reception following the ceremony you can share a glass of wine with your colleagues.

Complimentary refreshments will be served daily at both hotels 9:30–10:30 A.M. and 2:45–3:45 P.M.

Business Meetings and Section Luncheons/Dinner

The AGU Council will meet Tuesday, December 6, at 5:30 P.M.

The section lunches and dinner will be held at the following restaurants: Nikko, at Van Ness and Pine; Casa de Cristal, 1122 Post Street; A. Sabella's, on Fisherman's Wharf; and the Holiday Inn Golden Gateway.

Planetology/Volcanology, Geochemistry and Petrology

Tuesday, December 6, 12 P.M., Casa de Cristal, $9.

Seismology/Tectonophysics

Tuesday, December 6, 12 P.M., Nikko, $5.

Geomagnetism and Paleomagnetism

Wednesday, December 7, 12 P.M., Casa de Cristal, $5.

Hydrology

Wednesday, December 7, 12 P.M., Holiday Inn Golden Gateway, $9.

Solar-Planetary Relationships

Wednesday, December 7, 6 P.M., A. Sabella's, $20.

Atmospheric Sciences

Thursday, December 8, 12 P.M., Nikko, $9.

Geodesy

Thursday, December 8, 12 P.M., Holiday Inn Golden Gateway, $9.

Field Trip

On Sunday, December 4, 9 A.M. to 5 P.M., in connection with the Nano-Plate-Tectonic Symposium, there will be a field trip to the Franciscan nano-terranes in San Francisco, stressing their contact relations. The trip will be led by Clark Blake and Clyde Wahrhaftig.

The $25 per person cost includes tour bus, lunch, and field trip guide.

The trip will leave from and return to the Cathedral Hill Hotel.

The trip will be limited to 40 persons, and space will be reserved for the first 40 to sign up. Others can be put on a waiting list, or their checks can be returned, as they wish. Those interested should send the form printed in this issue with a check made out to M. C. Blake, Jr., addressed as indicated on the form. Be sure to mark on outside of the envelope "For AGU Doc. Field Trip."

his skill as a writer to gain recognition and his current position. He felt that working in an established group until he became part of the system was a valuable approach. Chris balances his career and home life by making sure housekeepers and babysitters are reliable, which helps both his career and marriage to survive.

Louise Levien went from graduate school to a post-doctoral research position at Caltech. This transition was motivated by purely scientific and career considerations. The move from California to Exxon was considerably different. She had decided not to apply for academic positions because research funding is so difficult for young scientists to obtain, and because she "was not prepared for a 7-year test". In addition, her long-time boyfriend had a job offer in Houston, so she agreed to look there, but only to accept a position she felt was viable on its own merits. Louise feels the positive sides of an industry job include more easily available research funding, fairly regular working hours, and a good salary. The negative sides of industrial positions are very limited vacation, massive changes in research projects, and the real possibility of being laid off.

Fred Spilhaus, partially motivated by patriotism, went from graduate school to the CIA. He turned around one of Chris Russell's comments by saying that "whatever you do, you might as well enjoy it." Fred's father, who was also his mentor, played a large part in his transition from the CIA to AGU. Fred disregarded the first request for an application to be assistant director of AGU. He then learned that the current director was retiring and that this position was created to bring in a new director for the Union. Fred's persistent mentor had a second application sent to him, and this time he applied. Fred stated that society work is very rewarding but strenuous and that he is traveling about 40% of the time.

Aviva Brecher talked in general about balancing scientific and personal goals as well as specifically about her own choices. She described a career-energy diagram in which some positions have high potential energy while others have high kinetic energy. There is always some activation energy associated with a career change, which can either provide a gradual or a drastic change. A learning curve is always associated with a new position, and a question to ask yourself is how steep do you want that curve to be? Aviva changed schools several times because her husband's career was more advanced, and she has worked both in academic and research positions. She emphasized the need for a very valuable skill in her present work at Arthur D. Little Co.: the ability to teach yourself. Given the heavy government funding of her work, Aviva now feels she needs more perspective from the other side and will be spending next year as a Congressional Fellow.

When Robin Brett finished his Ph.D., academic positions in Australia were limited, so he came to the Carnegie Institution of Washington's Geophysical Laboratory. Robin emphasized the part that luck, both good and bad, has played in shaping his career. His early work on ore deposits got him an offer to work on meteorities at NASA. Although he was challenged in his work, he felt Houston was not where he wished to settle. Robin stated that early in one's career the need to be flexible is important, whereas once established, more attention can be paid to personal preferences. He left NASA for USGS headquarters in Reston and from there became earth science director for the National Science Foundation (NSF). His move to NSF was made with the clear understanding that his position at the USGS would be available when his NSF appointment was completed. Robin feels that by applying knowledge from one field to another he has made contributions that allowed him to move to positions in varying fields. With his perspective within NSF he cautioned young scientists not to design their research to follow current funding.

The Education and Human Resources Committee plans to hold another panel discussion at AGU's 1983 Fall Meeting, in San Francisco, on Wednesday, December 7. The subject will be "two career couples," and couples are being sought to act as panelists (whether one or both are geoscientists). If you and your spouse would be willing to participate, please contact Connie Sancetta, Lamont-Doherty Geophysical Observatory, Columbia University, Palisades, NY 10964, telephone 914-359-2900, extension 412.

Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Nadhir Al-Ansari (H), Paul Allen, Patti J. Anderson (H), Harvey Belkin (V), Rumen D. Bojkov (A), Michel G. Bonhomme, Bernard Borcard (GP), Richard Brewer (S), G. Ali Dehghani, Michael P. Dempsey (G), F. Kim Devonald (O), Andrew G. Dickson (O), Eric F. Engbrecht (T), Carlos Elmer Ferro (S), Edward P. Foltyn (O), Darrell G. Fontane (H), Ryoichi Fujii (SM), Daniel H. Gaeddert (A), Barry Alan Goldstein (V), John Graves (T), Olafur Gudmundsson (S), Avijit Gupta (H), E. Anthony Haas (T), James C. Hare (T), Earl J. Hayter (O), Harold C. Helgeson (V), Roger A. Helvey (A), Kjell Henriksen (SA), Don Henriques (V), Yuzo Ishikawa, Albert Jambon (V), Kunio Kai, Michael D. Krom, Hiroshi Kumagai (SS), Michel B. Larue (T), Alfred G. Latham (GP), Thorne Lay (S), Ching-Yi C. Liao (S), Heung-Jae Lie (O), Theodore C. Loder (O), Robert F. Middelburg (H), David A. Mustart (V), Hans Peter Nuchtnebel (H), Sun Woo, Nahm (H), Francisco Navarro-Vila (T), Robert W. Nesbitt (V), Michael S. O'Day (T), David D. Parrish (A), Fausto Pasqualucci (A), Samuel T. Pees (T), George C. Pendleton (), Shyam Prasad (H), Victor A. Ramos (T), D. Rapp (O), George M. Reeves (H), Donald L. Rice (O), Stephen W. Richardson (T), Jeffrey E. Richey (O), Barbara J. Ryan (H), Karl Schroeder (S), Ludolf Schultz (P), Antonio Soares Correia (S), Erwin Suess (O), Paolo Tacconi (H), Minoru Takeo (S), Noriyuki Tanaka (V), William I. Thompson (A), Catherine L. Thornton (G), Ronald W. Tracy (T), Tadahide Ui (V), Nancy R. Vandenberg (G), Karel F. Wakker (G), Jeffrey P. Walker (A), Frank J. Williams (O), Stephen Wippel (S), Lucy R. Wyatt (O), Der Liang Young (H), Paul R. Young (S).

Student Status

Susan Q. Boundy (T), Michael A. Celata (S), Francis H. Chapelle (H), Catherine O. Constable (GP), Hyun-Chae Cynn (V), Bernadette L. Czuchra (S), H. Dannelongue (O), William S. Dershowitz (H), Goran A. Ekstrom (S), Andrew J. Friedland (A), A. James Friedson (P), Andrew J. Gratz (P), Stephen S. Harlan (V), Kenneth M. Hinkel (A), Mohammed Mozzammel Hoque (H), Jie Huang (S), Jonathan Istok (H), Christine Koltermann (H), S. M. Kong (S), Gail Sue Peretsman (V), Richard P. Rijnbeek (SM), Bill Schroeder (T), Thomas Southren (T), Judith Wright-Clark (V), Ding-Wen Yuan (GP).

AGU

Hydrology Section Actions

The framework of a new financing and publishing plan for *Water Resources Research* (WRR) was announced at the June 2, 1983, Hydrology Section Executive Committee meeting in Baltimore. In July, AGU General Secretary Leslie Meredith set rates based on the plan. The outline of the plan is as follows:

- The journal will begin monthly rather than bimonthly publication in January 1984.
- The member subscription rate will be $47 and the library subscription rate will be $220.
- There will be no page charge on the first 8 typeset pages of any paper.
- There will be a mandatory page charge of $125 on all pages over 8, except for invited review papers, for which there will be no page charges.
- As before, author-prepared copy is unacceptable unless identical to AGU typeset papers.
- Reprints will be available at $10 per page per hundred copies.

The Hydrology Section Executive Committee is further considering how best to meet the growing information needs of the Hydrology Section. Suggestions put forward include splitting WRR and/or developing a new journal. The first action would serve to contain the cost of WRR, which is increasing along with the increasing volume of high-quality material being submitted for publication. This action would carry with it the danger of deepening rather than reducing the differences among members of the section. A new journal would be intended to serve the more practically-oriented members of the section. Such a journal would of course be in direct competition with several existing, non-AGU journals. Is another one needed?

The executive committee would welcome written comments on these ideas.

Certification

A new organization known as the American Institute of Hydrology (AIH) and its associated Board of Registration has apparently come into being without prior consultation by its founders with AGU or with other concerned scientific and engineering societies (*Eos*, April 19, 1983, p. 146). Certification of hydrologists by AIH does not have any legal status: AIH is not backed by state or federal legislation as is common for Professional Engineer (PE) or Professional Geologist (PG) certification.

The Committee considered it questionable that there is a need for further certification routes (over and above PE and PG) for hydrologists; and it considered inappropriate a self-proclaimed certification body that is not aligned with existing scientific and professional societies. The committee agreed that AGU had no direct role to play in the certification or registration of "professional hydrologists" at this time and that the certification procedures available through the traditional registration bodies are currently adequate to satisfy society's needs for protection from unprofessional practice.

Horton Research Grant

The Horton Research Grant for 1983–1984 has been awarded to Jane Stockman, who is at the Department of Civil Engineering at Stanford University. The award, which carries a grant of $4500, was presented to Stockman at the Section luncheon on June 1. Her research topic is on the characterization of the dispersive properties of a heterogeneous, porous medium.

Committee on History

A Hydrology Section Committee on the History and Heritage of Hydrology has been formed, to be chaired by Bill Back; Marshall Jennings, Gerry Meyer, and Ed Landa have also agreed to serve. Bill would like to add three more members who are not with the USGS and whose area of interest is surface water. Anyone interested in this committee should contact Bill Back (703-860-6083) or Allan Freeze (604-228-6462).

The Committee plans to write up its purpose and goals in an article for *Eos* and then to schedule some History of Hydrology sessions, probably for the 1984 Fall and/or 1985 Spring Meetings.

Meetings

The executive committee judged the high point of the hydrology sessions at the AGU 1983 Spring Meeting to be the two-session symposium of Groundwater Flow and Fractured Rocks, which was attended by well over 100 hydrologists. The International Symposium on Urban Hydrology and the two sessions on the Nationwide Urban Runoff Program were also very successful. Thanks are due to Jack Robertson, Charley Faust, Jim Mercer and Jacques Delleur for their roles in organizing these sessions.

John Ritter, hydrology program chairman for the 1984 Spring Meeting in Cincinnati, and Dennis Lettenmaier, hydrology program chairman for the 1983 Fall Meeting in San Francisco, reported that a full slate of sessions is planned for their meetings.

The committee noted that poster session assignments still cause some problems. It is important that the section recognize and maintain the status of poster sessions as being equal to verbal presentations. In many ways poster sessions have an advantage over verbal presentations in that lengthy discussions can result between those who have mutual interests.

Section Committees

The Hydrology Section Committees and their chairmen for 1982–1984 are:

Erosion and Sedimentation Walter F. Megahan, USDA, Forest Service, 316 E. Myrtle St., Boise, ID 83702, 208-334-1457.

Remote Sensing Thomas J. Jackson, USDA Hydrology Lab., Beltsville, MD 20705, 301-344-3490.

Water Quality Kenneth H. Reckhow, School of Forestry and Environmental Studies, Duke Univ., Durham, NC 27706, 919-684-2802.

Ground Water John B. Robertson, USGS, EGS Mail Stop 410, Reston, VA 22092, 703-860-6976.

Precipitation Vijay K. Gupta, Dept. of Civil Engineering, Univ. of Mississippi, University, MS 38677, 601-232-5366.

Surface Runoff Keith Hipel, Dept. of Systems Design Engineering, Univ. of Waterloo, Waterloo, Ontario, Canada N2L 3G1, 519-885-1211, ext. 3113.

Water in the Unsaturated Zone Hubert J. Morel-Seytoux, Director, Engineering Research Center, Colorado State Univ., Fort Collins, CO 80523, 303-491-8549.

Snow and Ice Albert Rango, Hydrology Lab., Rm. 139, Bldg. 007, USDA/ARS/BARC-West, Beltsville, MD 20705.

History and Heritage William Back, USGS, Mail Stop 432, Reston, VA 22092, 703-860-6083.

Editor of *Eos* for Hydrology Mary P. Anderson, Dept. of Geology and Geophysics, Univ. of Wisconsin–Madison, 1215 W. Dayton St., Madison, WI 53706, 608-262-2396.

The activities of the Urban Hydrology Committee have been placed in the Surface Runoff Committee. The executive committee thanks Jacques Delleur and his committee members for their excellent work on the Urban Hydrology Committee and invites them to contact Keith Hipel to continue their activity.

Attending the executive committee meeting were Jared Cohon, Jacques Delleur, Peter Eagleson, Allan Freeze, Mark Houck, Ivan Johnson, Jurate Landwehr, Dennis Lettenmaier, Roy Sidle, Waldo Smith, Fred Spilhaus, Juan Valdes, and Jim Wallis.

Upgrading Teachers

The issue of government legislation to support the upgrading of secondary school science and math educators was the focus of AGU's Education and Human Resources (E & HR) Committee meeting held in Baltimore June 2, 1983, during AGU's 1983 Spring Meeting.

The committee discussed several ways in which AGU could be involved in encouraging teacher upgrading without subjecting other government-supported scientific projects to decreases. Committee Chairman Charles Hollister said he has talked to individuals that he knows on the House and Senate appropriations committees, and after the Senate version has passed he will report back to the E & HR committee. The question will be: Does AGU want to become involved, and if so, how?

On other topics, the following actions were taken.

- The final mockup of the *Careers in Oceanography* booklet was approved. It will be published this fall.
- It was agreed to continue the Job Centers at the national AGU meetings at their current level. They are serving a small number of attendees at almost no cost.
- The committee reviewed and revised a questionnaire for mailing to a select number of AGU members to help the committee evaluate the success of current programs and propose future projects.
- Louise Levien reported on the Spring Meeting special session on Career Choices: The Personal and the Scientific. An account of this session appears in this issue.

Those attending the committee meeting, besides Hollister, were committee members Laurie Brown, Louise Levien, Chris Russell and Connie Sancetta. Also attending was ex-officio member Robert Manka, AGU's representative to the Scientific Manpower Commission.

Comments on educational and human resources programs and questions of concern are welcome and should be addressed to the chairman of this committee at the AGU headquarters address.

Panel Discusses Career Choices

Career Choices: The Personal and the Scientific was the subject of the 1983 AGU Spring Meeting panel discussion sponsored by AGU's Education and Human Resources Committee. Laurie Brown (University of Massachusetts–Amherst) moderated the five-member panel of Aviva Brecher (Arthur D. Little Co.), Robin Brett (USGS), Louise Levien (Exxon Production Research Co.), Chris Russell (UCLA), and Fred Spilhaus (AGU).

In combining personal and scientific concerns into career choices, most panelists agreed on the need to be flexible about what you do, to do something you think you can do well, to keep a sense of humor, and, if possible, to use mentors and the network to help you find and acquire fulfilling positions.

Chris Russell has been at UCLA as a graduate student, on the research faculty, and now on the tenured faculty. He advised one to "be the world's expert in something," but do what you enjoy since you will be spending considerable time doing it. Chris said he used

GAP

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. ***Cost:*** $3.50 for the first article and $1.00 for each additional article in the same order. Payment must accompany order. Deposit accounts available.

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Aeronomy

0350 Pressure, density, and temperature
INCOHERENT-SCATTER MEASUREMENTS OF ION-NEUTRAL COLLISION FREQUENCIES AND TEMPERATURES IN THE LOWER THERMOSPHERE OF THE AURORAL REGION
C. Lathuillere (Centre d'Etudes des Phénomènes Aléatoires et Géophysiques, BP 46, 38402 Saint-Martin-d'Hères, France) V. Wickwar and W. Kofman

Incoherent-scatter observations performed in March and November 1978 at Chatanika have been used for studying the lower thermosphere in the auroral region. Neutral temperatures and densities have been found during periods without Joule heating. We present mean profiles of temperatures and collision frequencies (approximately proportional to neutral densities) for each month and profiles obtained during four specific nights. Between 93 and 110 km the mean profiles of temperature are in good agreement with the Jacchia 71 model and the profiles of collision frequency are similar to those deduced from the model. Consistency checks between these collision frequencies and temperatures were performed, as were various simulations of the data. Neutral temperature profiles between 95 and 140 km on the four specific nights show variations from one night to another that are not correlated to magnetic activity. However, there are systematic variations during each night that we suggest are due to atmospheric tides. (Lower thermosphere, ion-neutral collisions, auroral region, incoherent-scatter radar).
J. Geophys. Res., Blue, Paper 3A1346

0350 Pressure, density, and temperature
A REVISED THERMOSPHERIC MODEL BASED ON MASS SPECTROMETER AND INCOHERENT SCATTER DATA: MSIS-83
A. E. Hedin (Planetary Aeronomy Branch, Goddard Space Flight Center, Greenbelt, MD 20771)

The MSIS-83 empirical model of temperature, density and composition is a revision of the original MSIS model (including longitude/UT effects) and is based on temperature, density, and composition data from a comprehensive summary of rocket flights, seven satellites, and five incoherent scatter radars, including data from high solar activity. The model extends the previous description of neutral parameters to the base of the thermosphere in a continuous manner while maintaining the basic structure of the MSIS model at higher altitudes. As the altitude decreases, composition approaches lower atmosphere values while yearly, and to a lesser extent daily, variations in temperature and density are in reasonable agreement with previous results for the lower thermosphere. An alternate description of magnetic storm variations is provided based on the three hour ap indices and an 8 to 10 hour exponential decay in thermospheric density and temperature response after a heating event. Additional coefficients are included for the time independent and magnetic activity terms including a longitudinally dependent seasonal magnetic activity effect. The molecular oxygen description is based on mass spectrometer and EUV absorption measurements rather than ion chemistry.
J. Geophys. Res., Blue, Paper 3A1405

0460 Tides, waves and winds
OBSERVATIONS OF THE HIGH LATITUDE IONOSPHERE WITH THE POKER FLAT MST RADAR: ANALYSES USING SIMULTANEOUS CHATANIKA RADAR MEASUREMENTS
J. E. Lubmann (Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024) R. H. Johnson, H. J. Baron, B. B. Balsley and A. C. Riddle

The NOAA MST (Mesosphere-Stratosphere-Troposphere) VHF radar at Poker Flat, Alaska provides nearly continuous high time resolution measurements of the velocity of 3m scale plasma density irregularities at altitudes >85 km during the summer, and less continuous but lower (<65 km) altitude observations during the winter. However, incomplete knowledge of the origin and behavior of the VHF scatterers limits the applications of these data. Observations from the nearby Chatanika incoherent scatter radar are used to investigate the effects of electron precipitation and magnetospheric convection electric fields on the VHF observations. It is shown that the backscattered VHF signal is usually enhanced when auroral particles increase the D-region ionization. The magnetospheric convection electric fields do not generally affect the interpretation of the measured velocities of the 3m plasma irregularities as mesospheric winds. Combined neutral wind measurements from the two radars show some evidence for a continuous diurnal tide from the mesosphere through the thermosphere.
J. Geophys. Res., Blue, Paper 3A1400

Electromagnetics

0703 Antenna (Phased Arrays)
NORMALIZED RELATIONSHIP AMONG ERRORS AND SIDELOBE LEVEL
J. K. Hsiao (Radar Division, Naval Research Lab. Washington, D.C. 20375)

This paper examines the effect of errors on the peak sidelobe level of a phased array. The sidelobe level distribution of the radiation pattern for both linear and planar arrays is seen to be Rician. A set of constant probability curves is presented which relates the allowable phase and amplitude errors with the allowable sidelobe level deterioration. Examples are presented to demonstrate how these curves can be used to design a low sidelobe array with a better tolerance of error. These curves, or extensions of them, provide a useful tool for the engineer designing an array antenna. For a planar array with correlated errors the total variance σ is the root sum square (RSS) of the error in each element ($σ_u$, including both correlated and uncorrelated errors) and the contribution of correlated errors in a subarray ($σ_c$). Both $σ_u$ and $σ_c$ are functions of the errors and the illuminations, but $σ_c$ is also a function of the pattern of the subarray in which the errors are correlated (phased array sidelobe, array error tolerance).
Rad. Sci., Paper 3R1378

0703 Electromagnetics (Antennas)
IMPEDANCE OF A PLANE CAPACITOR IMMERSED IN A BEAM-PLASMA SYSTEM AND IN A STREAMING PLASMA
T. Fujita (Department of Electrical Engineering, Tohoku University, Sendai 980, Japan), S. Adachi

An impedance of a plane capacitor in a cold electron beam-electron plasma system is investigated theoretically. A radiation resistance results from excitations of two beam modes. It is found that the resistance becomes negative in a frequency range below an electron plasma frequency due to the effect of a two stream instability. As a special case, the impedance in a streaming collisionless plasma which includes no stationary plasma component is also discussed. This impedance is found to be very similar to the impedance for the stationary plasma having an equivalent collision frequency. (Antenna, Plasma, Instability).
Rad. Sci., Paper 3S1185

703 Antennas
NULL FIELD FORMULATIONS OF DIELECTRIC-COATED ANTENNAS
K. Aydin (Atmospheric Sciences Program and Department of Electrical Engineering, The Ohio State University, 2015 Neil Avenue, 467 Dreese Laboratories, Columbus, Ohio 43210), A. Altintas and A. Hizal

Null field formulations utilizing a generalization of the extended boundary condition method of Waterman are presented for dielectric-coated antennas of arbitrary but smooth shapes. Spherical, prolate spheroidal and spherically capped cylindrical antennas are solved as examples. Their power radiation patterns and input conductances are plotted as functions of coating thickness. The dielectric coating effectively increases the antenna size. Furthermore, it is shown that an eccentric coating can produce a considerable shift in the power radiation patterns. (Antennas, coated antennas, extended boundary condition, spherical vector wave functions).
Rad. Sci., Paper 3S1120

0720 Electromagnetic Theory
A NOTE ON THE VARIATIONAL METHOD (RAYLEIGH-RITZ), GALERKIN'S METHOD AND THE METHOD OF LEAST SQUARES
Tapan K. Sarkar (Department of Electrical Engineering, Rochester Institute of Technology, Rochester, New York 14623, USA)

Variational method (Rayleigh-Ritz), Galerkin's method and the method of least squares have been utilized extensively in electromagnetic theory to solve various field problems. In most cases, one makes a formal use of the techniques. In this paper, a tutorial approach has been taken to bring out the mathematical distinctions between the variational method (Rayleigh-Ritz), Galerkin's method, and the method of least squares. Examples have been presented to illustrate the strong and weak points of each of the techniques. Finally, the rates of convergence of the three techniques have been derived. It is hoped that with the appearance of this paper, application of a particular technique to solve an electromagnetic field problem would be more rigorous than formal. (variational method, Rayleigh-Ritz method, Galerkin's method, method of least squares, convergence, numerical technique, method of moments)
Rad. Sci., Paper 3S1007

0736 Media Effects
DETERMINATION OF CURRENT INDUCED ON A CONDUCTING STRIP EMBEDDED IN A DIELECTRIC SLAB
K. A. Michalski (Electrical Engineering Department, University of Mississippi, University, Mississippi, 38677) and C. M. Butler

Integral equations for the current density on a TM- and a TE-excited conducting strip embedded in a dielectric slab are derived and solved numerically. The Sommerfeld-type integrals incorporated in the kernels of the integral equations are evaluated numerically along various specified paths in the complex spectral plane, and a path switching criterion is used to maximize the efficiency of the integration. Results are presented for current induced on strips in lossy and lossless slabs for both plane wave and line current excitations. The effects of varying slab thickness, strip width, displacement of the strip from the slab center, and the loss tangent of the slab material on the current distribution are demonstrated. (Conducting strip, dielectric slab).
Rad. Sci., Paper 3S1162

Geochemistry

1120 Chemistry of bodies of water
GEOCHEMISTRY OF THE AMAZON 2. THE INFLUENCE OF GEOLOGY AND WEATHERING ENVIRONMENT ON THE DISSOLVED LOAD
R. F. Stallard (Department of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08544) and J. M. Edmond

In the Amazon Basin, substrate lithology and erosional regime (seen in terms of transport-limited and weathering-limited denudation) exert the most fundamental control on the chemistry of surface waters within a catchment. Secondary effects, such as the precipitation of salts within soils and in stream beds, biological uptake and release, and cyclic salt inputs, are more difficult to discern.

Samples can be separated into four principal groupings based on relationships between total cation charge (TZ+) and geology. (1) Rivers with 0<TZ+<200 μeq/l drain the most intensely weathered materials (Upper Tertiary sediments, soils of the Negro Basin and similarly weathered regions). These rivers show high levels of Fe, Al, H⁺ and coloration, and are enriched in Si relative to other major species; they exhibit cation ratios similar to those of substrate rocks. (2) Rivers with 200<TZ+<450 μeq/l drain siliceous terrains. These rivers are also rich in silica relative to other species. Rivers draining weathering-limited siliceous terrains exhibit the highest TZ+ and their cation load is typically preferentially enriched in Na over K and Ca over Mg when compared to the rocks in their catchments. (3) Rivers with 450<TZ+<3000 μeq/l drain marine sediments or red beds with high cation concentrations (resulting from the presence of carbonates and minor evaporites in the Peruvian Andes, and red-bed shales and minor carbonates in the Bolivian Andes). These rivers exhibit relatively high levels of Ca, Mg, alkalinity, and [illegible] (in rivers draining red-bed shales and minor evaporites). (4) Rivers with [illegible] μeq/l drain massive evaporites. These rivers are rich in Na and Cl. In catchments [illegible] and [illegible], rivers tend to have 1:1 equivalent ratios of Na:Cl and (Ca+Mg):alkalinity, [illegible] caused primarily by the weathering of carbonates and evaporites. (River chemistry, weathering, continental erosion, Amazon)
J. Geophys. Res., Green, Paper 3C1157

Geodesy and Gravity

1905 Artificial Satellite Techniques
DIRECT DETERMINATION OF GRAVITATIONAL HARMONICS FROM LOW-LOW GRAVSAT DATA
C. A. Wagner (National Geodetic Survey, Charting and Geodetic Services, National Ocean Service, National Oceanic and Atmospheric Administration, Rockville, Md. 20852)

An efficient method is developed to compute gravitational harmonics from low-low satellite-satellite range rate measurements. The satellites are assumed to be in nearly the same low eccentricity orbits. The residual range rate signal is modeled with frequencies derived from linear perturbation theory to an accuracy of about 99 percent. Significant nonlinear effects involving J_2, not currently modeled, require both J_2 and J_3 to be known in the reference trajectories. Each harmonic (l,m) generates l+1 principal frequencies, but they are not unique. Yet it appears possible to design a low altitude mission which keeps the pair at nearly constant separation and where the frequencies for all terms to (180,180) are separable after only about 4 weeks. A simple demonstration of the method is shown to recover (in two iterations) a complete (4,4) model (less J_2 and J_3) from 1 day of 'perfect' measurements (every 7 minutes) generated by numerical integration. In this result, the effects of orbit determination are included in a crude way but no other gravitational effects (of higher degree or from luni-solar attraction) are present. Nevertheless, the method is easily extended to high degree with rapid new techniques (which are described) for calculating the required inclination functions of the orbits. (Harmonic analysis, satellite-to-satellite tracking)
J. Geophys. Res., Red, Paper 3B1323

1940 Polar wobble
AUTOREGRESSIVE HARMONIC ANALYSIS OF THE EARTH'S POLAR MOTION USING HOMOGENEOUS ILS DATA
B. Fong Chao (Geodynamics Branch, Goddard Space Flight Center, Greenbelt, Maryland 20771)

The 80 year long (1900–1979) homogeneous set of International Latitude Service (ILS) polar motion data is analyzed using the 'Autoregressive method' (Chao & Gilbert, 1980) to resolve and produce an estimate for the complex frequency and complex amplitude for each harmonic component in the data, i.e., the annual wobble, the 14-month Chandler wobble, the Markowitz wobble with a period of about 30 years, and a linear secular drift (or polar wander).

The estimate for the secular drift of the pole of 3.25×10⁻³/yr agrees well with earlier investigations. The 30-year Markowitz wobble is shown to be marginally retrograde, but appears to exhibit a complicated behavior which cannot be resolved because of the shortness of the data set. The estimated period of the annual wobble agrees with the theoretical value of 365.25 days. The amplitude and phase of the annual wobble fluctuate rather little over the years; no evidence was found to support the larger variations reported by earlier investigators. The results obtained for the Chandler wobble support the argument that the Chandler wobble itself is a multiple-component motion. It is found that the Chandler wobble in the ILS data can be adequately modeled as a linear combination of four coherent sinusoidal components with nominal periods of 406.65, 426.08, 437.43 and 452.56 days. All four components exhibit an almost circular, prograde rotation of the pole. This is taken as strong evidence for the validity of the four-component model, for this coherent behavior is inconsistent with the hypothesis of a single component excited in a temporally and/or spatially random fashion. Furthermore, the four-component model 'explains' the apparent phase reversal during 1920–1940 and the pre-1950 empirical period-amplitude relation of the Chandler wobble. (Harmonic analysis, polar motion, multiple component of Chandler wobble).
J. Geophys. Res., Red, Paper 3B1408

Geomagnetism and Paleomagnetism

2560 Time variations, paleomagnetism
PALEOMAGNETISM OF THE LATE CRETACEOUS-EARLY TERTIARY NORTH-CENTRAL MONTANA ALKALIC PROVINCE
J.F. Diehl (Dept. of Geol. & Geol. Engrg., Michigan Tech. Univ., Houghton, MI 49931), M.E. Beck, Jr., S. Beske-Diehl, D. Jacobson, and B.C. Hearn, Jr.

Paleomagnetic results have been obtained from the Late Cretaceous-early Tertiary igneous complexes of the north-central Montana alkalic province. Data from 94 sites in Eocene volcanic and intrusive rocks give a paleomagnetic pole located at 82.0°N, 170.2°E (A_{95} = 3.5°; k = 18.6) while 36 sites in Paleocene intrusions yield a paleomagnetic pole at 81.8°N, 181.4°E (A_{95} = 5.4°; k = 20.2). These poles differ by only 1.6° and are not significantly different statistically. The 130 site VGP's show no significant elongation and suggest no significant APW during the period of magnetization of the igneous centers. Post-magnetization structural complications in those rocks are minimal. The presence of a single predominant polarity in those intrusive complexes reinforces the radiometric age data that suggest that igneous activity within individual centers was of short duration.

The north-central Montana data together with other early Tertiary, Cretaceous and mid-Tertiary paleomagnetic results require modification of our earlier APW chronology (Diehl, et al., 1980). It now appears that APW relative to North America since the early Cretaceous consists of a polar stillstand during much of the Cretaceous (120–75 m.y.b.p.), a period of rapid movement in latest Cretaceous time (75–65 m.y.b.p.) and a period of slow polar movement thereafter. The onset of this period of rapid APW correlates well with a major change in plate motions at ~80 m.y. and the beginning of the Laramide Orogeny. (Early Tertiary, paleomagnetism, polar wander, stillstand).
J. Geophys. Res., Red, Paper 3B1409

2599 Miscellaneous (Detrital remanent magnetism)
PALEOMAGNETISM OF TWO LATE PLEISTOCENE LAKE BASINS IN COLORADO: AN EVALUATION OF DRM AS A RECORDER OF THE GEOMAGNETIC FIELD
J. G. Rosenbaum (U. S. Geological Survey, Denver, Colorado, 80225) and E. E. Larson

Paleomagnetic studies of magnetite-bearing lacustrine sediments from two Late Pleistocene sections in Colorado, indicate that detrital remanent magnetization of fine-grained (silty-clay) sediments at both locations was capable of recording changes in the magnetic field over periods as short as 100 to 200 years, whereas, coarser grained silts in one of the sections seem to be less efficient recorders of the geomagnetic field. The remanence of the fine-grained sediments contains an apparent inclination error of about 9° at both localities. In addition, locally operative depositional and/or post-depositional processes have produced both intra- and interbasinal systematic differences in the remanence records of up to about 30° in declination and 10° in inclination. Comparison of the directional data from those sections with those from four other broadly contemporaneous North American lake basins reveals general similarities in the longer wavelength features, particularly of declination. However, abundant minor and several major discrepancies exist. The greatest difficulty in determining the significance of the similarities and differences between the records from the various lakes is the present lack of precise age and stratigraphic control. (Detrital remanent magnetism, secular variation).
J. Geophys. Res., Red, Paper 3B1257

Hydrology

3110 Erosion and Sedimentation
SUPPLY-BASED MODELS OF SUSPENDED SEDIMENT TRANSPORT IN STREAMS
J. VanSickle and R. L. Beschta (Department of Forest Engineering, Oregon State University, Corvallis, Oregon, 97331)

Sediment supplies and stream discharge together determine the patterns, over time, of suspended sediment loads in small streams. Most of the uncertainty in empirical streamflow-sediment relationships can be attributed to changing supplies. Our transport model utilizes a power function of the form $C = aQ^b$, where C and Q are sediment concentration and stream discharge, respectively. This expression was augmented with a variable S representing sediment storage in the channel system. The resulting supply-based model was calibrated to concentration and streamflow time series data from four storm events in a small, forested watershed in coastal Oregon. We also calibrated the model to data from a controlled reservoir release in Utah, during which streamflow was held constant for an extended period. In all cases, the supply-based model followed observed concentration time series more accurately than did a transport model based on Q alone. We further enhanced performance of the supply-based model by distributing sediment supplies S among several compartments which were accessed at different levels of stream discharge. Both the single-compartment and distributed models demonstrate that a knowledge of sediment supplies can improve predictions of suspended sediment concentrations during storm runoff. (Sediment transport, suspended sediment, water quality models).
Water Resour. Res., Paper 3W0527

3110 Erosion and sedimentation
PARTICULATE DYNAMICS, DISSOLVED AND TOTAL LOAD, IN TWO SMALL BASINS, NORTHERN PENNINES, UK
P. A. Carling (Freshwater Biological Association, The Ferry House, Far Sawrey, Ambleside, Cumbria, UK)

Suspended sediment and dissolved load were measured in two upland piedmont gravel-bedded streams for one year. In addition, the input of major cations from precipitation and the cation content of springs within the basins were monitored. The dynamics of the suspended load through a series of storm flows are examined in relation to sediment supply and progressive exhaustion effects. The variation in the grain size of the inorganic fraction of the particulate load during the passage of the floods is detailed and variations in the organic content of the load assessed. Two distinct models of dissolved cation concentration response to stream discharge variations are proposed which reflect differences in basin geology. Finally total load calculations are presented for the year. (Suspended sediment, dissolved load, particulate dynamics, Pennines UK)
Hydrological Sciences J. vol. 28, no. 3.

3130 Groundwater
EXPERIMENTAL INVESTIGATIONS OF UNCONFINED AQUIFER POLLUTION FROM RECHARGE BASINS
Yaruttanabhira Guvanasen and Raymond E. Volker (Department of Civil and Systems Engineering, James Cook University, Townsville, Queensland, Australia.)

Experimental data from a sandbox illustrate patterns of movement of a conservative contaminant away from a long strip recharge basin in an unconfined aquifer. Sodium chloride is used as a tracer with its distribution being monitored by electrical conductivity measurements controlled and stored through a minicomputer. The results were obtained for the case of negligible density variation and show that contaminant movement can be considered in two phases, the first involving vertical mixing under the basin and the second involving horizontal movement and mixing away from the recharge zone. The experiments indicate that the initial aquifer depth significantly influences the thickness of the mixing zone as well as the shape of the contaminant front in the vertical plane. Comparisons with the experimental results confirm that satisfactory solutions can be obtained from a finite element numerical model of the mass transport. (Groundwater, recharge, pollution, mass transport).
Water Resour. Res., Paper 3W0376

3130 Groundwater
REGIONAL MANAGEMENT OF AN AQUIFER FOR MINING UNDER FUZZY ENVIRONMENTAL OBJECTIVES
I. Bogardi, A. Bardossy (TISZADATA Consulting Engineers, Nagy Lajos Kiraly u. 23, A-1148 Budapest, Hungary) and L. Duckstein

A methodology is developed for the dynamic multiobjective management of a multipurpose regional aquifer. In a case study of bauxite mining ore deposits are under the piezometric level of a karstic aquifer, while this same aquifer also provides recharge flows for thermal springs. N+1 objectives are to be minimized, the first one being total discounted cost of control by dewatering or grouting; the other N objectives consist of the flow of thermal springs at N control points. However, there is no agreement among experts as to a set of numerical values that would constitute a "sound environment": for this reason a fuzzy set analysis is used and the N environmental objectives are combined into a single fuzzy membership function. The model is linearized and solved as a bi-objective dynamic program using multiobjective compromise programming. A numerical example with N=2 appears to lead to realistic control policies. Extension of the model to the non-linear case is discussed. (Groundwater management, fuzzy set, multiobjective decision making, mining).
Water Resour. Res., Paper 3W1368

3130 Groundwater
AN ISOTOPIC INVESTIGATION OF A NEAR-SURFACE GROUNDWATER SYSTEM
S. K. Gupta (Physical Research Laboratory, Ahmedabad 380009, India)

The distribution of environmental tritium, deuterium and oxygen-18 in the unsaturated zone and the underlying sandy phreatic aquifer was studied throughout 1981 in an area of high pine forests in the Rhine valley near Heidelberg. The observed vertical distribution of isotopes in the unsaturated zone can be satisfactorily explained by the combined use of a multi-cell model for moisture transport and an evapotranspiration model. The distribution in the underlying aquifer of the tracer input at the water table obtained using this method is found by replacing the total vertical diffusion coefficient in the diffusion equation with the dispersion coefficient. In this way observed tritium profiles are satisfactorily simulated for the period 1966–1981. The stable isotope profile in the unsaturated zone however remains largely unexplained due to inadequate data on the stable isotope content of precipitation over the investigated area. (Isotopes, groundwater, Rhine valley, model)
Hydrological Sciences J. vol. 28, no. 2.

3130 Groundwater hydrology (Infiltration)
ESTIMATION OF GROUND-WATER RECHARGE [illegible]
F. [illegible] (Mathematics Department, New Mexico Institute of Mining and Technology, Socorro, New Mexico, 87801).

A model is proposed that relates water-level fluctuations in a [illegible] aquifer to effective precipitation at the top of the unsaturated zone. Effective precipitation, defined herein as that portion of precipitation which becomes recharge, is related to precipitation measured in a nearby rare by a two-parameter function. A second-order stationary [illegible] is assumed to [illegible] the spectra of effective precipitation and water-level fluctuations. Measured precipitation is assumed to be Gaussian, in order to develop a transfer function that relates the spectra of [illegible] parameters of the effective-precipitation function. Although sensitivity analyses indicate difficulties that may be encountered in the estimation procedure, the methods developed did yield convergent estimates for two case studies. (Groundwater, soil moisture, precipitation).
Water Resour. Res., Paper 3W1263

3130 Hydrology (Groundwater)
STEADY-STATE FLUID RESPONSES IN FRACTURED ROCK: A BOUNDARY ELEMENT SOLUTION FOR A COUPLED, DISCRETE FRACTURE-CONTINUUM MODEL
A. M. Shapiro (Technion – Israel Institute of Technology, Faculty of Civil Engineering, Water Resources Division, Technion City, Haifa 32000, Israel), and Johan Andersson

A discrete fracture representation of a highly fractured groundwater aquifer is inappropriate as a modelling approach since the location of all fractures can never be explicitly specified. However, the alternative of exclusively employing a continuum description of the medium then neglects any geologic information that exists with regard to the location of specific fractures in such formations. In order to take better advantage of geologic information in highly fractured aquifers a model is proposed which couples the discrete fracture and continuum conceptualizations. In regions where discrete fractures are designated, an efficient means of computing the steady-state fluid responses is formulated with the use of the boundary element method. This allows the consideration of highly complex fracture geometries, since fluid responses in the porous rock are described with a set of linear equations written only in terms of the hydraulic head and fluid mass flux at the boundaries the porous rock shares with the fractures. One-dimensional equations of fluid movement in the fractures written in terms of the same variables make coupling of the two systems straight forward. In this technique, discretization only along the fractures is required. Thus, the internal discretization of the host rock that would be characteristic in the use of finite difference and finite element methods is alleviated. At the boundary of the region where specific fractures are identified, a continuum conceptualization is coupled to the discrete fracture model. Steady-state fluid responses in the continuum domain are defined using a semi-analytic technique which is based on the discretization of Green's Third Identity. The resulting coupled model allows the discrete fracture and continuum conceptualizations to be employed in the modelling of those areas where they are judged to be most appropriate, based on the availability of physical information.
Water Resour. Res., Paper 3W0526

3130 Groundwater
[illegible] NEW PROCEDURES FOR NUMERICAL SOLUTION OF VARIABLY SATURATED FLOW PROBLEMS
Richard L. Cooley (U.S. Geological Survey, WRD, P.O. Box 25046, MS 413, DFC, Denver, CO 80225)

Persistent difficulties that arise in forming numerical solutions of variably saturated flow problems include controlling the stability of the nonlinear-equation solvers and devising a reliable, yet efficient, method for determining the positions of seepage surfaces. New techniques for addressing these problems are applied to a subdomain finite-element discretization of the governing flow equations. A series of test problems demonstrates that the techniques are reliable and efficient for a wide variety of problems. (Variably saturated flow, finite element methods, nonlinear equations).
Water Resour. Res., Paper 3W1150

3140 Limnology (Acidic Precipitation)
SENSITIVITY OF FLORIDA LAKES TO ACIDIC PRECIPITATION
D.E. Canfield, Jr. (School of Forest Resources and Conservation, University of Florida, Gainesville, Florida 32611).

To assess the potential vulnerability of Florida lakes to damage by acidic precipitation, data from a survey of 165 lakes located in the major physiographic and geologic regions of Florida were used to determine pH, total alkalinity, calcium hardness and calcite saturation index values. Mean lake pH ranged from 4.1 to 8.9. Mean total alkalinity concentrations ranged from 0 to 4100 µeq/l and mean calcium hardness concentrations ranged from 30 to 4300 µeq/l. Total alkalinity averaged below 200 µeq/l in 49% of the sampled lakes. Calcite saturation index values were greater than 4 in 56% of the sampled lakes. Based on these data, Florida has a large number of lakes that are vulnerable to reductions in pH and alkalinity by acidic precipitation. Data on chlorophyll a concentrations, zooplankton abundance and recent fisheries data, however, suggest Florida lakes may not be as biologically sensitive as the alkalinity and calcite saturation indices might suggest. Low phosphorus and nitrogen concentrations are primarily responsible for reduced animal and plant populations in acidic Florida lakes. Consequently, predictions of future impacts or trends based on current sensitivity indices should be regarded with caution. (Acidic precipitation, eutrophication, alkalinity, pH).
Water Resour. Res., Paper 3W0457

3160 Runoff and streamflow
IMPROVED PARAMETER INFERENCE IN CATCHMENT MODELS, PART II: COMBINING DIFFERENT KINDS OF HYDROLOGIC DATA AND TESTING THEIR COMPATIBILITY
George Kuczera (Water Supply Division, Melbourne and Metropolitan Board of Works, Box 4342, Melbourne, Victoria, 3001, Australia)

Often some of the parameters of catchment models fitted to runoff data are poorly-determined thereby making the task of developing useful regionalisation relationships more difficult. The Bayesian methodology developed in Part I is extended to utilise several kinds of hydrologic data in parameter inference, the goal being to improve the precision of poorly-determined parameters. The concept of compatibility is developed using statistical hypothesis tests. Different kinds of data are said to be compatible if differences between their fitted parameters are not statistically significant. The pooling of incompatible data may undermine the model's ability to predict runoff and also induce bias in the parameters. A hierarchy of three levels of information is introduced to enable systematic checking for compatibility. Finally a case study is presented. Using data on runoff, soil moisture and interception it is shown that substantial reductions in parameter uncertainty can be realized; also the importance of compatibility testing is demonstrated.
Water Resour. Res., Paper 3W1117

3160 Runoff and Streamflow
ANALYZING ALTERNATIVE FLOOD DAMAGE REDUCTION MEASURES ON SMALL RURAL WATERSHEDS USING MULTIPLE RETURN PERIOD FLOODS
I.C. Goulter (Department of Civil Engineering, University of Manitoba, Winnipeg, Manitoba, R3T 2N2) and D.R. Morgan.

A heuristic technique for the analysis of alternative flood damage reduction measures on small rural watersheds is presented. The technique is based on dynamic programing. The watershed is divided into a series of sequential reaches or stages. The tradeoffs between storage of floodwaters on marginal upstream land parcels and the reduction in crop damages downstream are evaluated. Allocation of flood resistant crops to the frequently flooded storage areas is considered. The duration of flooding is incorporated into the flood damage functions. The use of cumulative storage volume as the state variable permits the explicit evaluation of expected annual flood damage costs through the consideration of multiple return period floods. The use of cumulative storage volume as the state variable implies that the hydrograph shape at any stage is independent of the spatial distribution of the storage upstream of that stage. Since this condition cannot be guaranteed this technique must be classed as heuristic. The procedure is demonstrated by application to the Wilson Creek Watershed in Manitoba, Canada.
Water Resour. Res., Paper 3W1235

3160 Runoff and Streamflow
A BAYESIAN SURROGATE FOR REGIONAL SKEW IN FLOOD FREQUENCY ANALYSIS
George Kuczera (Water Supply Division, 10th Floor, MMBW, Box 4342, Melbourne, 3001, Australia)

The problem of how to best utilize site and regional flood data to infer the shape parameter of a flood distribution is considered. One approach to this problem is given in Bulletin 17B of the U.S. Water Resources Council for the log-Pearson distribution. Here a lesser known distribution is considered – namely, the power normal which fits flood data as well as the log-Pearson and has a shape parameter denoted by λ derived from a Box-Cox power transformation. The problem of regionalizing λ is considered from an Empirical Bayes' perspective where site and regional flood data are used to infer λ. The distortive effects of spatial correlation and heterogeneity of site sampling variance of λ are explicitly studied with spatial correlation being found to be of secondary importance. The end product of this analysis is the posterior distribution of the power normal parameters expressing, in probabilistic terms what is known about the parameters given site flood data and regional information on λ. This distribution can be used to provide the designer with several types of information. The posterior distribution of the T-year flood is derived. The effect of non-linearity in λ on inference is illustrated. Because uncertainty in λ is explicitly allowed for, the understatement in confidence limits due to fixing λ (analogous to fixing log skew) is avoided. Finally, it is shown how to obtain the marginal flood distribution which can be used to select a design flood with specified exceedance probability.
Water Resour. Res., Paper 3W0496

3160 Runoff and streamflow
IMPROVED PARAMETER INFERENCE IN CATCHMENT MODELS, PART I: EVALUATING PARAMETER UNCERTAINTY
George Kuczera (Water Supply Division, Melbourne and Metropolitan Board of Works, Box 4342, Melbourne, Victoria, 3001, Australia)

A Bayesian methodology is developed to evaluate parameter uncertainty in catchment models fitted to a hydrologic response such as runoff, the goal being to improve the chance of successful regionalization. The catchment model is posed as a nonlinear regression model with stochastic errors possibly being both autocorrelated and heteroscedastic. The end result of this methodology, which may use Box-Cox power transformations and ARMA error models, is the posterior distribution which summarizes what is known about the catchment model parameters. This can be simplified to a multivariate normal provided a linearization in parameter space is acceptable – means of checking and improving this assumption are discussed. The posterior standard deviations give a direct measure of parameter uncertainty and study of the posterior correlation matrix can indicate what kinds of data are required to improve the precision of poorly-determined parameters. Finally, a case study involving a 9-parameter catchment model fitted to monthly runoff and soil moisture data is presented. It is shown that use of ordinary least squares when its underlying error assumptions are violated gives an erroneous description of parameter uncertainty.
Water Resour. Res., Paper 3W1116

3170 Snow and Ice
PORTRAIT OF AN ANTARCTIC OUTLET GLACIER
Siegfried Meier (Technische Universität Dresden, Mommsen Str. 13, GDR)

The Hays Glacier of Enderby Land is a small Antarctic outlet glacier with a "sack-shape" source region of as yet not exactly known southward extent and area (approximately 10^4 km²). It has a uniform or slightly wavy longitudinal profile, an approximately 7 km wide calving front between 46°15' and 46°20'E, and a partly floating glacier tongue, extending to the seasonally changing front (classification 424 118 according to UNESCO-IAHS, 1970). The longitudinal mean surface slopes are 5–8 m km⁻¹ on the tongue, 20–30 m km⁻¹ in the step-shaped central section, and 8–12 m km⁻¹ in the entrance region. The glacier is bordered to 15 km south of the front by about 500-m-wide crevasse belts, associated in some places with pressure ridges. It is distinctly separated from the continental ice sheet by three rock walls on the eastern edge. At the western edge the glacier has a secondary influx region of 40 km² area which is crevassed and feeds a well-defined tributary into the left part of the glacier tongue. The average flow direction of the glacier is north, changing to northorthwest at the front. The outflow velocity is of the order of 1000 m a⁻¹, and the annual iceberg production in Spooner Bay (the southeastern section of Alasheyev Bay in the Cosmonaut Sea) is approximately 3 km³. The dynamic conditions along the glacier are inferred from geodetic, strain, and accumulation measurements, and using a modelled internal temperature distribution. (Glacier, portrait, Antarctic)
Hydrological Sciences J. vol. 28, no. 3.

3175 Soil moisture
MOVEMENT OF FINE GRAINS IN THE VICINITY OF WELL SCREENS
György Kovács and László Ujfaludi (Research Centre for Water Resources Development (VITUKI), PO Box 27, H-1453 Budapest, Hungary)

A great number of laboratory experiments have been performed to study the flow generated suffusion process in soil samples supported by perforated screens. Both parallel and radial flow were tested in typical example of the latter in a well-screen supporting the material of an aquifer. The soil samples tested were theoretically divided into two parts: a coarse grained fraction which behaves as a self-supporting skeleton, and a fine-grained fraction filling the pores of the skeleton. Experimental results showed that the process of soil suffusion occurs with increasing flow velocity. At low velocities the fine grains maintain their original position and the flow can be described by Darcy's law. Reaching a critical velocity $v^{(1)}_{cr}$ the fine grains start to move, partially plugging the pores of the skeleton, while resistance of the sample is increasing. Reaching a second critical flow velocity $v^{(2)}_{cr}$ results in the development of microchannels, through which fine grains may move out from the layer. The quantity of these fine grains depends on the composition of the soil sample, the flow rate and the slot-diameter of the well-screen. On the basis of the experimental results empirical formulae have been developed for calculating the critical velocities $v^{(1)}_{cr}$ and $v^{(2)}_{cr}$, and the optimum slot sizes of the screen. (Suffosion, well-screen, flow, fine grains)
Hydrological Sciences J. vol. 28, no. 2.

3175 Soil moisture
RAINWATER INFILTRATION INTO A BARE LOAMY SOIL
S. D. Sharma (ICAR Research Complex for NEH Region, Shillong 793003, India)

In order to design micro-catchment water harvesting systems in the Indian desert, rainwater infiltration experiments were conducted on a representative loamy sand soil for a period of six years. Plots with three slopes – 0.5, 5 and 10 %, and five slope lengths – 5.12, 7.0, 8.5, 10.75 and 14.5 m were used. With dry antecedent soil conditions, infiltration is governed by rainfall depth, whereas with wet antecedent soil conditions, rainfall impact (intensity) which forms a crust over the soil surface, is the deciding factor. Infiltration decreases significantly with increasing slope due to reduction in the time available for rainfall to infiltrate, but slope length has no significant effect. A graphical multiple curvilinear model to predict rainfall infiltration using rainfall and basin characteristics is developed and the goodness of fit is tested. (Rainwater, infiltration, basin characteristics, India)
Hydrological Sciences J. vol. 28, no. 3.

3175 Soil Moisture
ESTIMATING SPATIAL VARIABILITY IN SOIL MOISTURE WITH A SIMPLIFIED DYNAMIC MODEL
R.B. Clapp (Department of Civil Engineering, University of Maryland, College Park, Maryland 20742), G.M. Hornberger and B.J. Cosby

Observed spatial variability of soil moisture in the field may be due to several factors. Topographic effects, soil heterogeneity, and spatial variability in precipitation and vegetation may induce variability in measured soil moisture. Scaling theory has been suggested as a promising tool for describing soil heterogeneity and, consequently, a portion of spatial variability of measured soil moisture.

We investigate the appropriateness of ascribing soil moisture variability to heterogeneity of soil properties through the use of a model of soil moisture dynamics and scaling theory. The model, termed a wetting-front model, is a simplified representation of water content in soils. The model conceptually depicts the moisture profile as discrete blocks of soil moisture separated by sharp fronts.

Probabilistic simulations were run with input data appropriate to watersheds R-5 and R-7 at Chickasha, Oklahoma. Results from the simulations indicate that variability due to soil heterogeneity remains relatively constant through time with only slight increases during redistribution following infiltration. Comparison of simulated and observed soil moisture integrated from the surface to the 15-cm depth shows that heterogeneity in soil hydraulic properties may account for approximately 75% of observed standard deviation. (Soil water, spatial variability, scale theory, simulation).
Water Resour. Res., Paper 3W0384

3180 Water quality
THE REGIONAL EFFECTS OF THE EFFLUENTS FROM THE MISHRAQ SULPHUR MINES IN IRAQ ON THE HYDROLOGICAL SYSTEM
Riadh H. Al-Dabbagh and Maha A. S. Al-Dabbagh (University of Mosul, Mosul, Iraq)

Sulphur is mined at Mishraq near Mosul, Iraq, by the injection of superheated water. The production area is adjacent to and in contact with the River Tigris. With time an increasing number of hot sulphur springs have erupted in and near the river. Geological and hydrological studies have shown that faults, fractures and cavities in the predominantly limestone rocks increase the hydraulic conductivity and seepage coefficient. The most effective method of controlling the large-scale flow of sulphur into the river was by pumping a barrier of cold water into observation wells bored into areas of high hydraulic conductivity, in order to solidify the sulphur. (Tigris, sulphur, pollution)
Hydrological Sciences J. vol. 28, no. 2.

3180 Hydrology (Water Quality)
CONTROL OF DO LEVEL IN A RIVER UNDER UNCERTAINTY
H.C. Spear (Department of Biomedical and Environmental Health Sciences, University of California, Berkeley, California 94720), G.M. Hornberger

A previously developed regionalized sensitivity analysis for exposing critical uncertainties in models of environmental systems is extended to study control of systems for which there is a good deal of uncertainty in the mathematical model used to describe the appropriate physical, chemical and biological processes. The method is based on a binary classification of Monte-Carlo simulation results as being either satisfactory or unsatisfactory in terms of controller performance. Contrasts in parameters associated with the two classes are elucidated by statistical analysis. This allows the selection of a set of control parameters that maximizes the probability of acceptable behavior in the presence of uncertainty in process parameters. The method is applied to the problem of regulating the discharge from a lagoon with the object of preventing DO from falling below a predetermined standard. It was found that for this system the desired behavior of the controlled process can be achieved with a probability of 0.84 with a particularly simple controller design. Nevertheless the results suggest that even modest levels of uncertainty in the process parameters can have a considerable effect on the controller performance and that additional attention should be devoted to the design of robust controllers for environmental systems. (Dissolved oxygen, control, sensitivity analysis).
Water Resour. Res., Paper 3W1224

3180 Water quality
WATER QUALITY MANAGEMENT WITH TIME VARYING RIVER FLOW AND DISCHARGER CONTROL
J.P. Herbay, Y. Smeers (Center for Operations Research and Econometrics, Université Catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium) and D. Tyteca.

An extension of the classical river quality management problem is presented that allows for time varying operation of the treatment plants. The hydrology of the river is represented by a set of steady-state flow regimes; a river water quality model is used for each of these regimes to give a constraint set to be imposed on the discharges, in order to achieve the stream standards during that regime. The objective function distinguishes between investment costs, fixed operating costs, and variable operating costs. A treatment system is sought that minimizes the sum of operating costs, taking account of the possibility of operating the treatment system at various different levels during the year. The model is quantified and illustrated on an example. (Water quality, management, time varying control, river quality).
Water Resour. Res., Paper 3W1386

3180 Water Quality
EVALUATION OF IRRIGATION WATER QUALITY FOR A SPATIALLY VARIABLE FIELD
Eshel Bresler (U.S. Salinity Laboratory, Riverside, California 92501), D. Yaron, and A. Segev

A model to predict the optimal salt concentration of irrigation water when various sources of water are available is described. The model employs a stochastic model for soil water and solute movement, and a programming economic model for best solutions over an extended time period. Soil water flow is assumed steady and irrigation or rainfall is assumed to be uniform. Transient solute transport is assumed to obey the diffusion-convection equation. The probability of a given average root zone salinity after irrigation or rain is calculated for any combination of applied water salinity and initial soil salinity using a probability density function for the saturated hydraulic conductivity. The expectation of the total income from a crop yield having a known response function to soil salinity is maximized subject to a given probability of the average root zone salinity exceeding a prespecified critical concentration. The cost of water is assumed to decrease as the salinity of irrigation water increases. Optimal water management depending on the salt concentration of the irrigation water over 6 years is illustrated for citrus in terms of minimum cost, maximum income, optimum salt concentration of the irrigation water, spatial distribution of average root-zone salinity and the probability of exceeding a prescribed critical soil salinity concentration. (Solute transport, water flow, stochastic model, linear programming).
Water Resour. Res., Paper 3W1361

3190 Instruments and techniques
ON BACKWATER EFFECTS IN LINEAR DIFFUSION FLOOD ROUTING
James C. I. Dooge (Department of Civil Engineering, University College, Upper Merrion Street, Dublin 2, Ireland)
Zbigniew W. Kundzewicz and Jaroslaw J. Napiórkowski

The effect of the downstream boundary condition on the flow in a channel reach as predicted by the linear diffusion analogy model is analysed by both Laplace transformation and by modal analysis. In each case the solution takes the form of an infinite series. It is shown that the series based on Laplace transformation is highly convergent for small times and the series based on modal analysis is highly convergent for medium and longer times. (Backwater effects, flood routing, Laplace transformation)
Hydrological Sciences J. vol. 28, no. 3.

3190 Instruments and Techniques
OBSERVING WATER SURFACE AND STREAMBED CHANGES WITH THE ACOUSTIC VELOCITY MEASURING SYSTEM
Antonius Laenen (Water Resources Division, U.S. Geological Survey, 847 N.E. 19th Ave., Suite 300 Portland, Oregon 97232)

Acoustic velocity metering systems used to measure the water velocity along a diagonal path across a stream can also be used to measure stage and streambed changes. Underwater acoustic transmissions reflected from the water surface can accurately measure depth above transducers. Similarly, reflected signals from the streambed can indicate streambed changes in the vicinity midway between transducers.
Water Resour. Res., Paper 3W1222

3190 Instruments and techniques
ANALYTICAL SOLUTION FOR TRANSIENT TWO-DIMENSIONAL UNCONFINED GROUNDWATER FLOW
T. D. Nguyen and A. J. Raudkivi (Department of Civil Engineering, University of Auckland, Private Bag, Auckland, New Zealand)

The solution, with the aid of the enclosed function, provides a quick and easy method of estimating the phreatic line and flow rate as a function of time into a large cut, such as a mining excavation. (Groundwater, flow rate, opencast mining)
Hydrological Sciences J. vol. 28, no. 2.

3190 Instruments and techniques
APPLICATION OF A BAYESIAN MODEL TO DETECT SHIFTS IN THE MEAN OF A SERIES (in French)
Pierre Bruneau (Service Hydraulique, Projets de centrales, Hydro-Québec, 855 est Ste-Catherine, 14ième étage, Montreal, Canada H2L 4P5)
and Jean-Claude Rassam

A Bayesian model has been applied on the annual and monthly flow series of the Sainte-Anne du Nord River in order to check the influence of the regulation of four reservoirs on the monthly series in terms of a shift δ in the mean at time τ. The same model has been tested on two other series, thus permitting identification of those shifts that would be attributed to regionally observed climatic variations. (Bayesian model, flow series, mean, Sainte-Anne du Nord River)
Hydrological Sciences J. vol. 28, no. 3.

3190 Instruments and techniques
DAILY PRECIPITATION OCCURRENCES MODELLING WITH MARKOV CHAIN OF SEASONAL ORDER
Maria Mimikou (Civil Engineering Department, Technical University of Athens and Public Power Corporation, Athens, Greece)

The seasonality of the Markov chain order for properly modelling daily precipitation occurrences for precipitation stations in Greece is studied. The average seasonal storm duration, being the average seasonal ratio of the number of wet days to the number of storm events and influenced by the meteorology and geography of the station, is proposed as a criterion for determining the proper seasonal Markov order. For the records studied, and on a monthly basis, the latter, minimizing the chain's modelling error, is the closest positive integer to the average storm duration in days reduced by one. Orders greater than 1 are prevalent in wet periods, whereas in dry periods orders of 1 or 0 predominate. The appearance of the period with orders higher than 1 is delayed and its duration decreases towards the east and with decreasing altitude. The monthly sums of wet days are modelled better by a second order autoregressive model than by aggregating daily precipitation occurrences generated from a Markov chain. (Markov chain, model, daily precipitation, Greece)
Hydrological Sciences J. vol. 28, no. 2.

3190 Instruments and techniques
AN APPLICATION OF NETWORK DESIGN PROCEDURES FOR REDESIGNING KIZILIRMAK RIVER BASIN RAINGAUGE NETWORK, TURKEY
Ünal Sotman (UNITEK Ltd, Architects and Engineers, P.K. 53, Kavaklidere, Ankara, Turkey)
and Güven Balkan

Recently developed rainfall network design techniques are discussed and compared. Present day hydrological studies require high levels of accuracy from collected data. Also, scientists need to know the degree of accuracy of the information they use. The existing rainfall network in the Kizilirmak basin must be redesigned in order to meet the required level of accuracy needed by rainfall data users. The three following techniques were applied: optimum interpolation procedure which is a flexible method; variance of mean areal rainfall; and the analysis of variance. The existing network of 54 gauges is redesigned so that the network will have an average root mean square error (rmse) of 5.32 cm and the percentage of the area with rmse ≥ 15 cm is limited to 10%. It is found that the proposed criteria are satisfied by a network of 51 gauges of which eight were newly established and seven of the existing ones removed. (Raingauge network, design, accuracy, Turkey)
Hydrological Sciences J. vol. 28, no. 2.

3199 General or miscellaneous
HYDROLOGICAL RESPONSE PATTERNS OF SOME THIRD ORDER STREAMS ON THE BASEMENT COMPLEX OF SOUTHWESTERN NIGERIA
J. O. Adejuwon (Department of Geography, University of Ife, Ile-Ife, Nigeria)
L. T. Jeje and O. O. Ogunkoya

The hydrological response patterns of some third order rivers in southwestern Nigeria are described in terms of regime, discharge variability and recession of flow from peak discharge in the rainy season to the lowest minimum discharges of the dry season. The maximum and minimum discharges of the rivers coincide with the rainy and dry seasons respectively. Most of the rivers exhibit erratic flow with quick responses to storms and storm water abating quickly, while some have a very low groundwater contribution to streamflow, a phenomenon which accounts for their drying up for considerable periods in the year. The variability indices of discharge of the rivers range from 0.25 to 2.12 while the recession constants range from 0.64 to 0.98. The variability indices are much higher than those of basins of similar size reported from other studies. Three types of rivers are recognizable on the basis of their hydrological response patterns. It is observed that the nature of the surficial and solid geology has a greater influence on discharge characteristics than other factors such as depth of regolith and rainfall. (Discharge, regime, recession, Nigeria)
Hydrological Sciences J. vol. 28, no. 3.

3199 General (Reservoir Operation)
RELIABILITY CONSTRAINED RESERVOIR CONTROL PROBLEMS: 2. RANDOMIZED STRATEGIES
M. Suicdovich (NRIMS of the CSIR, P.O. Box 395, Pretoria 0001, South Africa), and F.A. Nielsen

The concept of 'randomized strategies' is examined in the context of reservoir control problems. It is shown that such strategies are not likely to be used by decision-makers adopting a purely frequency-based approach to probability and statistics. Certain conceptual issues associated with the implementation of randomized strategies are clarified and illustrated. (Reservoir control, randomized strategies).
Water Resour. Res., Paper 3W1363

3199 General or miscellaneous
EFFECTS OF BIOCLIMATE AND SOIL USE ON WATER BUDGET TERMS IN WEST AFRICA (in French)
E. Roose, F. Lelong and J. Colombani (ORSTOM, 70–74 route d'Aulnay, F-93140 Bondy, France)

Comparative water budgets have been established by measurement (rainfall, runoff, soil moisture) and calculation (evapotranspiration, drainage) on six experimental plots in West Africa throughout a bioclimatic sequence from the lower Ivory Coast to central Upper Volta. These budgets show the variations of water budget terms with bioclimate, soil use and pedological characteristics. In non cultivated plots (natural vegetation) the runoff term is low whatever the vegetation (12–2% of annual rainfall). Deep drainage is near zero when annual rainfall is less than 900–1000 mm (equatorial areas) and less than 700–800 mm (tropical areas). In cultivated plots, runoff increases greatly but total flow (runoff + deep drainage) does not necessarily increase. Thick soils, with important water storage support increased evapotranspiration at the expense of drainage. (Water budget, bioclimate, soil use, West Africa)
Hydrological Sciences J. vol. 28, no. 2.

Meteorology

3715 Chemical Composition and Chemical Interactions
NITROGEN OXIDES IN THE TROPOSPHERE: GLOBAL AND REGIONAL BUDGETS
J.A. Logan (Center for Earth and Planetary Physics, Harvard University, Cambridge, MA 02138)

The cycle of nitrogen oxides in the troposphere is discussed from both global and regional perspectives. Global sources for NO_x are estimated to be of magnitude 50(±25)×10¹² gm N yr⁻¹. Nitrogen oxides are derived from combustion of fossil fuels (~40%) and biomass burning (~25%) with the balance from lightning and microbial activity in soils. Estimates for the rate of removal of NO_x based on recent atmospheric and precipitation chemistry data are consistent with global source strengths derived here. Industrial and agricultural activities provide approximately two thirds of the global source for NO_x.

In North America, sources from combustion of fossil fuels exceed natural sources by a factor of 3–13. Wet deposition removes about one third of the combustion source of NO_x over North America, while dry deposition removes a similar amount. The balance is exported from the continent. Deposition of nitrate in precipitation over eastern Canada and the western Atlantic is clearly influenced by sources of NO_x in the eastern United States. Major uncertainties in the cycle of NO_x are attributed to lack of field measurements and inadequate understanding of heterogeneous processes involving NO_x. (Nitrogen oxides, tropospheric chemistry, global budgets).
J. Geophys. Res., Green, Paper 3C1377

3715 Chemical Composition and Chemical Interactions
KINETIC STUDIES OF RAINDROP CHEMISTRY
1. INORGANIC AND ORGANIC PROCESSES
T.E. Graedel (Bell Laboratories, Murray Hill, NJ 07974) and K.I. Goldberg

The chemistry of raindrops, though not long ago to be adequately represented by a few simple ions and their equilibrium constants, is now recognized to involve the complex reactions of ions, radicals, and molecules of both acidic and basic moieties. To describe this system, we have formulated a model which includes both inorganic and organic processes (but not metal catalysis) totalling 94 reactions in 33 species. Three sets of computations were performed for raindrops of different diameters. In the first two, the initial chemistry of the raindrops was set by the cloud chemistry measurements of APEX (Atmospheric Precipitation Experiment) in the northeastern US. In the simulations, the drops were released into tropospheric air characteristic of either the suburban or urban northeast. In the third set of computations, designed to simulate urban centers on the US west coast, raindrops with compositions typical of those over the oceans were dropped in urban tropospheric air. The results demonstrate that photochemical processes, including the photolysis of H_2O_2 to produce OH· and the photolysis of NO_3^- to produce ozone, are significant in raindrop chemistry, that organic chemical reactions of interest and importance occur in raindrops, particularly those of small size (and thus long lifetime), and that significant differences in some species concentrations occur at different altitudes during the raindrop's fall, and for drops of different diameters.
J. Geophys. Res., Green, Paper 3C1374

3715 Chemical composition and chemical interactions
LATITUDINAL DISTRIBUTION AND TEMPORAL CHANGES OF STRATOSPHERIC HCl AND HF
William G. Mankin and M. T. Coffey (National Center for Atmospheric Research*, Boulder, Colorado 80307)

Hydrogen chloride and hydrogen fluoride are important sinks in the stratosphere for free halogens. The major sources of chlorine and fluorine in the stratosphere are anthropogenic; therefore a measurement of HCl and HF gives information about the magnitude of anthropogenic effects on stratospheric chemistry, and may give some information about the stratospheric hydroxyl concentration as well. We have determined the total column amount of HCl and HF above 12 km by measuring infrared absorption spectra with a high resolution Fourier transform spectrometer flown on a jet aircraft. The HCl column varies from 0.7 × 10¹⁵ molecules-cm⁻² near the equator to 2.7 × 10¹⁵ molecules-cm⁻² at 70°N; the HF column is about a factor of five lower. The HCl:HF ratio is almost independent of latitude, and neither constituent shows substantial seasonal or diurnal variation. At midlatitudes, the data from 1978 to 1982 show an annual increase of 5% per year for HCl and 12% per year for HF. (HCl, HF, stratospheric halogens, latitudinal distribution)
J. Geophys. Res., Green, Paper 3C1428

3720 Climatology
ON THE ABSENCE OF SELF-OSCILLATORY BEHAVIOR IN SOME ZERO-DIMENSIONAL CLIMATE MODELS
R. G. Watts (Department of Mechanical Engineering, Tulane University, New Orleans, Louisiana 70118)

The auto-oscillatory behavior of some zero-dimensional energy balance models stems directly from a misinterpretation of the Sellers parameterization of the variations of albedo with temperature. When a globally averaged value of the Sellers albedo is used, these models do not exhibit auto-oscillation.
J. Geophys. Res., Green, Paper 3C1394

3746 Gravity Waves
STRATOSPHERIC-TROPOSPHERIC OZONE EXCHANGE IN ANTARCTICA CAUSED BY MOUNTAIN WAVES
E. Robinson, (Laboratory for Atmospheric Research, Washington State University, Pullman, Washington, 99164-2730), D. Clark, D. R. Cronn, W. L. Bamesberger, and A. W. Hogan.

Under suitable meteorological conditions mountainous terrain may induce atmospheric wave formations that propagate across the tropopause and into the stratosphere. This study presents results of a NSF C-130 research aircraft flight over the Ellsworth Mountains of Antarctica (78°S, 85°W) on 3–4 December 1978. The aircraft flew a total of 14 flight tracks generally parallel to the mountain ridge at 4 primary altitudes between 7.3 and 8.7 km, MSL. Data analyses included horizontal and cross section fields of temperature, potential temperature, ozone, frost point, and wind. Over the mountain area there was a pattern of changes that could be explained by the apparent vertical motion expected to occur in mountain wave situations. At various constant levels the measured values appeared to be organized into a series of zones characteristic of wave troughs and ridges oriented across the mean wind direction and parallel to the terrain ridges. Ozone flux calculations showed that at about 7.4 km, 1.1 km below the tropopause, the flux was 268 µg m⁻² s⁻¹. This was a 61% mountain wave zone was 268 µg m⁻² s⁻¹. This was a 61% increase over the incoming ozone flux of 167 µg m⁻² s⁻¹. The downwind flux was larger above 7.4 km. It is concluded that the increases in ozone observed in the downwind tropospheric layers were the result of mountain wave-induced downward mixing of ozone-rich stratospheric air parcels.
J. Geophys. Res., Green, Paper 3C1303

3770 Meteorology
CHARACTERIZATION OF AEROSOLS IN MARINE ENVIRONMENT (MEDITERRANEAN, RED SEA AND INDIAN OCEAN)
F. Prodi (Indirizzare a: Laboratorio Fisbat – C.N.R., Via de' Castagnoli 1, 40126 Bologna (Italy), G. Santachiara and F. Oliosi

A study of the aerosol in different marine environments was performed during a scientific cruise on the vessel Salernum from the Mediterranean Sea to the Indian Ocean (January 1st to February 27th, 1979). The aerosol particles were sampled on membrane filters and in a single-stage impactor. The particles on the filters were analyzed for soluble Mg, Ca, K, Na, for mineral aerosol mass concentration and for chloride particles. An elemental analysis using the microprobe attached to the scanning electron microscope (SEM) was carried out. The aerosol particle size distribution was determined from the photographs of the filter surface taken by the SEM. The concentration of the ice-forming nuclei was measured by developing the filters in a static diffusion chamber. Chloride particles were also independently detected on the single-stage impactor slides.

The data, also discussed in association with the atmospheric turbidity measurements taken during the same cruise, give a clear picture of the aerosol characteristics which reflect in a detailed and sensitive way the origin of the air mass in which they were sampled.
J. Geophys. Res., Green, Paper 3C1384

3770 (Particles and aerosols)
SAGE AND SAM II MEASUREMENTS OF GLOBAL STRATOSPHERIC AEROSOL OPTICAL DEPTH AND MASS LOADING
G.S. Kent (Institute for Atmospheric Optics and Remote Sensing, 17 Research Drive, Hampton, Virginia) and M.P. McCormick, NASA, Langley Research Center, Hampton, Virginia

Several volcanic eruptions between November 1979 and April 1981 have injected material into the stratosphere. The SAGE and SAM II satellite systems have measured, with global coverage, the 1 µm extinction produced by this material and examples of the data product are shown in the form of global maps of stratospheric optical depth and altitude-latitude plots of zonal mean extinction. These data, and that for the volcanically quiet period in early 1979, have been used to determine the changes in the total stratospheric mass loading. Estimates have also been made of the contribution to the total aerosol mass from each eruption. It has been found that, between early 1979 and mid-1981, the total stratospheric aerosol mass increased from a background level of approximately 570,000 metric tons to a peak of approximately 1,300,000 metric tons. (Stratospheric aerosols, volcanic injection, satellite extinction measurements).
J. Geophys. Res., Green, Paper 3C1314

3790 Meteorology (Instruments and Techniques)
PROPERTIES OF MULTI-LAYERED CLOUD SYSTEMS FROM SATELLITE IMAGERY
James A. Coakley, Jr. (National Center for Atmospheric Research, Boulder, CO 80307

The spatial coherence method for obtaining fractional cloud cover from satellite imagery is extended to the case of multi-layered cloud systems. Examples are presented in which simultaneous observations at 3.7 µm and 11 µm are used to solve a system of linear equations for the nonoverlapped fractional cover contributed by each of two layers. The retrieval relies on the assumption that the clouds reside in distinct, well-defined layers, and are optically thick at the wavelengths of observation. Simultaneous observations at 3.7 µm and 11 µm of the separate layers indicate that the assumptions are generally valid. Owing to the reflection of solar radiation at 3.7 µm by low level water clouds, the method is limited to nighttime observations. (Clouds, satellite imagery, remote sensing).
J. Geophys. Res., Green, Paper 3C1345

Mineralogy, Petrology, and Crystal Chemistry

4220 Experimental mineralogy and petrology
VISCOSITY-TEMPERATURE RELATIONSHIPS AT 1 ATM. IN THE SYSTEM DIOPSIDE-ANORTHITE
[illegible] (Department of [illegible], University of Washington, [illegible] Washington, D.C. 20005), D.J. Cronin, J.I. Wenzel and D.A. Kauffman (Center for Materials Science, National Bureau of Standards, Washington, D.C. 20234)

Laboratory measurements of the viscosities of nine compositions on the diopside-anorthite join were made with a concentric-cylinder viscometer at temperatures between approximately 1200–1600 °C in air. Viscosities were measured both above the liquidus and in the supercooled liquid region. Viscosities were independent of shear rate, indicating Newtonian viscous behavior for the melts. Viscosities decreased with increasing temperature and, at constant temperature, they decreased with increasing amounts of diopside component in the mixtures. The temperature dependence of the viscosity above the liquidus was fitted to an Arrhenius relationship from which activation energies for viscous flow, ranging from 60 kcal/mole for a melt of anorthite composition to 39 kcal/mole for a melt of diopside composition, were derived. Viscosities over the entire range of melt and supercooled liquid temperatures were fitted by the method of least squares to the Fulcher equation. The fit was better than 0.02 in log viscosity.

The present experimental results are systematically lower at any temperature than the earlier measurements of Kozu and Kani (1935). Viscosity is strongly dependent on the amount of alumina in the melt and on temperature. As diopside is added to anorthite melt, there is a modification of the three-dimensional network structure in favor of a more depolymerized structure. Activation energies for viscous flow, however, suggest that this change does not take place gradually across the join and that there are fundamental differences in the flow properties of liquids of diopside composition compared to alumina-bearing melts along the join. (1 atm. viscosity, melts, diopside-anorthite system).
Am. Min., 68, 9-10

4220 Mineralogy (Descriptive Mineralogy)
ALLOGENIC LAYER SILICATE MINERALS IN BOREHOLE ELMORE #1, SALTON SEA GEOTHERMAL FIELD, CALIFORNIA
S. D. McDowell (Dept. of Geol. & Geol. Engrg., Michigan Technological University, Houghton, MI 49931)

Reaction of coarse grained allogenic layer silicate minerals with hot, hypersaline brine of the Salton Sea Geothermal System has resulted in the formation of a series of metastable intermediate mineral phases that were created within the system, have a finite temperature range over which they exist, and react with the system in a regular but incomplete manner. Intense calcite and dolomite/ankerite cementation allowed a suite of allogenic biotite, chlorite, and muscovite grains to be preserved as unstable mineral phases to temperatures near 200°C. At this stage removal of significant portions of the cement and access of the fluid phase to these minerals initiated a series of complex reactions.

Muscovite reacted to very fine grained interlayered illite/smectite through a phengitic muscovite intermediate phase that persists in the geothermal system for less than 30°C. The overall reaction of muscovite occurred in two steps, the first involving change within the 2:1 layer via Mg addition and Al loss but little change in the interlayer sheet, and the second involving significant K loss in the interlayer site to expandable smectite layers with subsequent Mg fixing. Allogenic Ti-bearing biotite reacted completely at temperatures near 200°C to a metastable titaniferous chlorite phase by a reaction mechanism that apparently allowed the 2:1 octahedral sheet of the reactant biotite to be preserved intact in the product chlorite. The metastable chlorite persists throughout the entire chlorite zone, shows some systematic compositional variation with temperature, but was steadily reduced in amount by reaction to fine-grained Ti-free equilibrated authigenic chlorite. At the biotite isograd at 325°C, the remaining metastable titaniferous chlorite reacted completely and rapidly to a metastable titaniferous biotite in a reaction that involved all structural sites in the minerals. This biotite reacted, within 10° above the biotite isograd, to Ti-free equilibrium authigenic biotite.

A significant degree of the compositional scatter observed in low grade metamorphic layer silicate minerals may be due to the existence of metastable mineral phases which have preserved structural elements of the mineral they originally replaced. The data suggest that those sites within minerals can remain inert while others continue to react with the fluid phase, creating partially equilibrated mineral phases and mineral reactions that must be dealt with on a site-by-site basis. (Geothermal mineralogy, metamorphism, layer silicates).
Am. Min., 68, 9-10

4260 Petrogenesis
MID-TO LATE-STAGE KIMBERLITIC MELT EVOLUTION: PHLOGOPITES AND OXIDES FROM THE FAYETTE COUNTY KIMBERLITE, PENNSYLVANIA
Robert H. HUNTER, Randall D. KISSLING, and Lawrence A. TAYLOR (Dept. of Geol. Sci., Univ. of Tennessee, Knoxville, TN 37996)

Hypabyssal-facies kimberlite from Fayette County, Pennsylvania, comprises megacrysts/inclusions, peridotite xenoliths, and crustal fragments set in a matrix of phlogopite, spinel, ilmenite, perovskite, rutile, carbonate and minor serpentine. Two chemically distinct populations of megacrysts/inclusions are present: a Cr-rich suite (olivine (Fo 90-93), Cr-pyrope, Cr-diopside, enstatite, Cr-spinel, and immiscible sulfide melt products); and a Cr-poor suite (olivine (Fo 81-85), pyrope, diopside, and picroilmenite (16-37 mol% $MgTiO_3$)). These minerals record the evolution of two chemical distinct kimberlitic melts within the low velocity zone (LVZ). Olivines of both populations have rims of Fo 88-89, and ilmenite megacrysts possess reverse-zoned rims (34-51 mol% $MgTiO_3$). These zonations reflect mixing of the two populations of megacrysts and their host melts within the LVZ.

The chemical evolution of this hybrid belt during mid-to late-stages of the kimberlite's history is recorded by groundmass phlogopites and oxides. Phlogopites document increases in activities of Fe^{+}, Ca, and Na and a decrease in Cr-activity. Groundmass ilmenites are compositionally similar to ilmenite megacryst rims. Spinels show zonation from titanian Mg-Al-chromite (TMAC) through chromian Mg-Al-titanomagnetite (CMAT) to magnesian Al-titanomagnetite (MAT), reflecting increase in Ti and Fe^{3+} activities and decrease in activities of Cr and Mg during the evolution of the hybrid melt. Late-stage rutile indicates high activities of Ti and near-solidus temperatures. Ilmenite instability is a function of a late-stage increase in Ca activity with stabilization of Nb-, REE-bearing perovskite. Spinels reaction rims of ilmenite megacrysts are compositionally similar to CMAT in the groundmass adjacent to the matrix, they are zoned to MAT. Inhomogeneous distribution of sulphides and perovskite in the groundmass and variable modal proportions of spinel and perovskite in the ilmenite megacryst reaction rims indicate local variations in fugacities of O_2, S_2, and CO_2. (kimberlite, mantle petrology, geothermobarometry).
Am. Min., 68, 11-12

4260 Petrogenesis
MAGMA-MIXING IN THE LOW VELOCITY ZONE: KIMBERLITIC MEGACRYSTS FROM FAYETTE COUNTY, PENNSYLVANIA
Robert H. HUNTER and Lawrence A. TAYLOR (Dept. Geol. Sci., Univ. of Tennessee, Knoxville, TN 37996)

Two chemically distinct populations of megacrysts /inclusions are present in hypabyssal-facies kimberlite from Fayette County, S.E. Pennsylvania: A Cr-rich suite and a Cr-poor suite. The Cr-rich suite consists of olivine (Fo 90-93), garnet (1.6%-6.1% Cr_2O_3), diopside (1.0%-2.3% Cr_2O_3), Cr-spinel, and immiscible sulfide-melt products. The suite possesses a limited range of mg, and major element compositions of minerals are similar to those in sheared garnet-lherzolite xenoliths. Minor element variations are consistent with crystal fractionation over a temperature interval from 1310° to 1055°C in the pressure range 48-39 kb. The Cr-poor suite is more evolved and comprises olivine (Fo 81-85), garnet (<0.1% Cr_2O_3), picroilmenite (16-37 mol% $MgTiO_3$; 0.05-2.05% Cr_2O_3), and diopside (<0.1% Cr_2O_3). This suite represents a relatively advanced stage of fractionation of a Cr-poor melt within the LVZ. Mixing of these populations and their host melts has resulted in rim compositions of Fo 88-89 on both groups of olivines and reverse-zoned rims on the ilmenite megacrysts (34-51 mol% $MgTiO_3$; 1.4-3.6% Cr_2O_3).

The Cr-poor suite crystallized from ponded melts segregated from rising diapirs in the LVZ. Crystal fractionation in those melts led to evolved mineral compositions and ilmenite saturation. The Cr-rich suite represents crystal and immiscible sulfide-melt fractionation in a melt within an uprising diapir; melt/crystal ratio was low, and major element compositions in the melt were buffered by ambient mantle compositions (undepleted garnet lherzolite). Uprise of this melt-bearing diapir disrupted evolved, Cr-poor crystal mushes, incorporating megacrysts and resulting in mixing of the host melts. Back-reaction and crystallization of the cognate xenocrysts within the hybrid melt resulted in the zoning patterns observed. (kimberlite, mantle petrology, geothermobarometry).
Am. Min., 68, 11-12

4299 General (Thermoluminescence)
THE PARAMETERS OF INDUCED THERMOLUMINESCENCE OF SOME SELECTED PHYLLOSILICATES: A CRYSTAL DEFECT STUDY
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Induced thermoluminescence of five phyllosilicates, which vary with respect to chemical composition and physical characteristics, was investigated. In addition, these minerals were subjected to heating and cation fixation in order to determine the influence these processes had on induced thermoluminescence. The thermoluminescence de-excitation spectra yielded differences in glow curve intensity and electron trap activation energies as a function of clay mineral composition, charge deficiency characteristics and type of cation fixed with the clay sample.

Both potassium and lithium fixed samples demonstrated an increase in thermoluminescence glow curve intensity indicating the fixation of cations on clay surfaces and inside the crystal structure of clay minerals introduces new electron traps to the system. The increase in the number of electron traps due to potassium fixation is proportional to the degree of tetrahedral charge deficiency of the clay and is proportional to the total charge deficiency of lithium fixed montmorillonites. The average electron trap activation energy is highest for potassium fixed clays while cation fixation and heating a given clay reduces the maximum temperature and half-width of the induced thermoluminescence glow curve.
Am. Min., 68, 9-10

Oceanography

4705 Boundary layer and exchange processes
COLD-AIR OUTBREAKS OVER THE NORTHWEST FLORIDA CONTINENTAL SHELF: HEAT FLUX PROCESSES AND HYDROGRAPHIC CHANGES
O. K. Huh (Coastal Studies Institute, Louisiana State University, Baton Rouge, Louisiana, 70803), L. J. Rouse, Jr., and N. D. Walker

An experimental study of the meteorology and oceanography of the cold-air outbreak cycle was conducted during the fall of 1978 off Panama City, Florida. Details of the air-sea interaction processes they induce on such upwind continental shelves are poorly known because of lack of appropriate measurements. Shallow depths and proximity to land make the processes significantly different from their deepwater counterparts. The cycle has three phases recognizable in the measurements: the prefrontal, frontal passage, and cold-air outbreak/high-pressure phases. The time variability of oceanic heat fluxes was monitored through the cycle in two ways: by measuring heat content changes and with measurements of turbulent and radiative heat fluxes. Advective effects on the heat budget were minimized by the site selection. A mild cold-air outbreak stripped 26.8 × 10⁶ J m⁻² (640 cal cm⁻²) of heat and 1.1 cm of liquid water from the shelf in 63 hours, and a severe cold-air outbreak removed 147.8 × 10⁶ J m⁻² (3528 cal cm⁻²) and 4.4 cm of liquid water in 87 hours. For these events, evaporation, sensible heat loss, and radiative heat loss were 31%/16%/53% and 58%/25%/17% of the totals, respectively. A simple, one-dimensional, shallow-water heat flux model predicted temperature and heat content changes during severe cold-air outbreaks to within 8%. Observations indicate the extreme time variability of heat flux processes and the hazards of extrapolating to daily rates from spot measurements or very short time series. (Cold-air outbreaks, air-sea interactions, cooling, destratification, insolation)
J. Geophys. Res., Green, Paper 3C1422

4713 Circulation
RECENT PROGRESS IN THE APPLICATION OF SATELLITE ALTIMETRY TO OBSERVING THE MESOSCALE VARIABILITY AND GENERAL CIRCULATION OF THE OCEANS
L.-L. Fu (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109)

Recent progress in the application of satellite altimetry from SEASAT and GEOS 3 to the observation of the oceanic mesoscale variability and general circulation is reviewed. The lack of accurate geoid models has been the major obstacle in the study of the general ocean circulation from altimetry. The use of geoid-independent methods that utilize the temporal differences in altimetric measurements taken at

fixed locations, however, has made significant contributions to our knowledge of the mesoscale variability of the ocean. The mesoscale energies of the sea surface height and geostrophic current have been mapped on a global basis. Their distributions in wave number space have also been analyzed. Because of many of the deficiencies of existing altimeter data (short duration, inadequate orbit, poor accuracy, etc.) most of these results describe only a small portion of the frequency-wave number spectrum of the variability, but they have nonetheless demonstrated the great value of an optimally designed altimetric mission in advancing our knowledge of the global mesoscale variability. The current technology allows satellite altimetry to deter- oceanic variability at periods from a few days 3-5 years, wavelengths from 50 to 10,000 km. Determining the time-averaged general ocean circulation from altimetry is more problematic because an accurate geoid is indispensable. The currently available global geoid models have useful accuracies only at wavelengths greater than about 7,000 km. There have been several attempts at mapping the global ocean circulation at those scales using existing altimeter data and geoids. When these results are compared with hydrographic surveys, some qualitative agreement can be observed, but the quantitative differences are mostly inconclusive due to the geoid and orbit errors. It has been suggested, however, that an altimetric mission that is optimally designed with the current technology, when complemented by a state-of-the-art gravimetric mission to map the earth's gravity field, is able to determine the ocean circulation quantitatively at scales from the ocean basin to about 200 km. (General ocean circulation, mesoscale variability, satellite altimetry, geoid).
Rev. Geophys. Space Phys., Paper 3R1423

4713 Circulation
THERMOHALINE CIRCULATION BELOW THE ROSS ICE SHELF: A CONSEQUENCE OF TIDALLY INDUCED VERTICAL MIXING AND BASAL MELTING
Douglas R. MacAyeal (Department of Geophysical Sciences, University of Chicago, Chicago, IL 60637)
The warmest water below parts of the Ross Ice Shelf resides in the lowest portion of the water column because of its high salinity. Vertical mixing caused by tidal stirring can thus induce ablation by lifting the warm but dense water into contact with the ice shelf. A numerical tidal simulation indicates that vertically well-mixed conditions predominate in the southeastern part of the sub-ice-shelf cavity where the water-column thickness is small. Basal melting in this region is expected to be between 0.05 and 0.5 m/yr, and will drive a thermohaline circulation having the following characteristics: high-salinity-shelf water (at -1.9°C), formed by winter sea-ice production in the open Ross Sea, flows along the sea bed towards the tidal-mixing fronts below the ice shelf; and meltwater (at -2.2°C), produced in the well-mixed region, flows out of the sub-ice-shelf cavity along the ice-shelf bottom. Sensitivity of this ablation process to climatic change is expected to be small because high-salinity-shelf water is constrained to have the sea-surface freezing temperature. (Distributions and water masses, Glaciology)
J. Geophys. Res., Green, Paper 3C1427

4713 Circulation
ON DETERMINING THE LARGE-SCALE OCEAN CIRCULATION FROM SATELLITE ALTIMETRY
Chang-Kou Tai (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139)
To determine the surface geostrophic currents (which are proportional to the slope of the dynamic topography) from satellite altimetry, one needs an accurate and independent estimate of the geoid. Currently these estimates are given in terms of spherical harmonics. While the high-degree terms (short wavelengths) are either uncertain or completely unknown, the low-degree terms (long wavelengths) are reasonably accurate. Furthermore in terms of spherical harmonics, most of the dynamic topography's power is contained in the low-degree terms. If the dynamic topography is treated as the signal and the geoid uncertainty as the noise, the signal to noise ratio is the highest for these low-degree terms. Therefore a spherical harmonic expansion of the difference between the altimeter derived mean sea surface and the geoid estimate should reveal the large-scale circulation of the ocean surface layer when one examines the low-degree terms. Methods based on this principle are proposed and partially demonstrated over the Pacific Ocean using the mean sea surface derived from the Seasat altimeter and the GEM-9 earth gravity model. The preliminary results show a well-defined clockwise gyre in the North Pacific and a much less well-defined counter-clockwise gyre in the South Pacific. When the dynamic topography so obtained is compared to Wyrtki's [1975] dynamic topography derived from hydrographic data, the agreement is within the limit of geoid uncertainties and satellite orbital errors. To fully determine the three-dimensional ocean circulation, one still needs hydrography---the three-dimensional density distribution of the ocean. A method is presented for the determination of the ocean circulation and the improvement of the geoid in the combined problem of geodesy, hydrography, and satellite altimetry.
J. Geophys. Res., Green, Paper 3C1262

4740 Marine Geological Processes
A STOCHASTIC MODELLING APPROACH TO THE FINE SEDIMENT BUDGET OF THE NEW YORK BIGHT
T. L. Clarke (NOAA/AOML, Miami, FL 33149), D. J. P. Swift and R. A. Young
A stochastic model of fine sediment transport on the continental shelf is modified to include the effects of storm flows. The model, based on surface gravity wave resuspension, now includes transport by both tides and episodic storm flows. Effects of gravity wave/storm flow correlation as deduced from near bottom current meter measurements are also included. The effects of the gravity wave/storm flow correlation and the regionalnet flow pattern are small.
The model is solved numerically for equilibrium dispersal patterns for sediment entering at estuary inlets bordering the New York Bight region. Additional dispersal patterns are found for upcoast and downcoast sources as well as the dredge spoil dump site. Combinations of these dispersal patterns are least squares fit to the observed sediment distribution in the New York Bight to evaluate the magnitudes of the sources of sediment; negative source magnitudes are interpreted as sediment sinks. The results are consistent with other estimates of sediment sources and sinks in the New York Bight. (sediment transport, numerical model, estuarine flux).
J. Geophys. Res., Green, Paper 3C1342

4799 (General or miscellaneous)
DEFINITE INTEGRAL OF THE PRODUCT OF HERMITE FUNCTIONS, WITH APPLICATIONS TO THE THEORY OF NONLINEAR INTERACTIONS AMONG EQUATORIAL WAVES
P. Ripa (División de Oceanología, Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, BCN, México)
An analytic expression and an asymptotic estimate are derived for the definite integral of a product of Hermite functions (Hermite polynomial times a Gaussian). The argument of each Hermite function is proportional, but not necessarily equal, to the integration variable. The asymptotic estimate is used to show that the integral is negligible unless there are points where the sum of the *local* wave-numbers is zero. This result is used, in the context of geophysical fluid dynamics, to stablish a connection between the meridional interaction condition for *equatorial* waves, represented by Hermite functions, and *mid-latitude* waves, represented by sinusoids: for the latter it is the sum of the *constant* wavenumbers that has to vanish. (Hermite functions, nonlinear interactions, equatorial waves).
J. Geophys. Res., Green, Paper 3C1228

Particles and Fields—Interplanetary Space

5130 Shock waves
ELECTRON VELOCITY DISTRIBUTIONS NEAR INTERPLANETARY SHOCKS
W. C. Feldman (University of California, Los Alamos National Laboratory, Los Alamos, NM 87545), R. C. Anderson, S. J. Bame, J. T. Gosling, R. D. Zwickl, and E. J. Smith (Jet Propulsion Laboratory, Pasadena, CA)
Solar wind electron velocity distributions measured across interplanetary shocks using the Los Alamos plasma analyzer on ISEE-3 have been studied to understand electron heating mechanisms for weak and intermediate strength collisionless shocks. This study thus complements earlier studies of electron heating at the earth's bow shock, an example of a highly supercritical collisionless shock. At the weakest interplanetary shocks (downstream-to-upstream density ratio, $N(d/u) \leq 2$ and velocity difference, $V(d-u) \leq 70$ km/s) heating perpendicular to the magnetic field, B, predominates over parallel heating. Such heating may be a consequence of conservation of magnetic moment across the shock. At the stronger interplanetary shocks ($N(d/u) > 2$ and $V(d-u) > 70$ km/s) heating parallel to B is dominant and the downstream velocity distributions are flat-topped, similar to what is observed downstream of the earth's bow shock. This similarity suggests that electron heating in all collisionless shocks with $N(d/u) > 2$ and $V(d-u) > 70$ km/s results, in part, from an acceleration parallel to B produced by the macroscopic shock electric field, followed by beam driven plasma instabilities.
J. Geophys. Res., Blue, Paper 3A1404

5380 Solar Wind Plasma (Composition)
SOLAR WIND IRON ABUNDANCE VARIATIONS AT SPEEDS > 600 km s^{-1}, 1972-1976
D. G. Mitchell (Applied Physics Laboratory, Johns Hopkins University, Laurel, Maryland, 20707), E. C. Roelof, and S. J. Bame
We have analyzed the Fe/H ratios in the peaks of high speed streams during the decline of Solar Cycle 20 and the following minimum (October 1972–December 1976). We utilized the response of the 50-200 keV ion channel of the APL/JHU energetic particle experiment (EPE) on IMP-7 and 8 to solar wind iron ions at high solar wind speeds ($V \geq 600$ km sec^{-1}), and compared our Fe measurements with solar wind H and He parameters from the Los Alamos National Laboratory (LANL) instruments on the same spacecraft. In general, the Fe distribution parameters (bulk velocity, flow direction, temperature) are found to be similar to the LANL He parameters. Although the average Fe/H ratio in many steady HSS peaks agrees within observational uncertainties with the nominal coronal ratio of 4.7×10^{-5}, abundance variations of a factor of up to 6 are obtained across a given coronal-hole associated high speed stream. There are, as well, factor of 2 variations between stream-averaged abundances for recurrent high speed streams emanating from different coronal holes occurring on the sun on the same solar rotation. Flare-related solar wind streams sometimes show Fe/H ratios enhanced by factors of 4-5 over coronal-hole associated, quiet time streams. Over the period 1973-1976, a steady decrease in the average quiet-time Fe/H ratio by a factor ~4 is measured on both IMP-7 and 8. (Iron abundance, high speed solar wind, spatial and temporal trends)
J. Geophys. Res., Blue, Paper 3A1108

Particles and Fields—Ionosphere

5505 Airglow
$O(^1S)$ FROM DISSOCIATIVE RECOMBINATION OF O_2^+: NON-THERMAL LINE PROFILE MEASUREMENTS FROM DYNAMICS EXPLORER
T. L. Killeen and P. B. Hays (Space Physics Research Laboratory, Department of Atmospheric and Oceanic Science, the University of Michigan, Ann Arbor, Michigan 48109).
Direct measurements at high spectral resolution of the $O(^1S)$ emission line profile at 5577 Å made using the Fabry-Perot Interferometer on Dynamics Explorer are reported. The line profile is found to have marked non-thermal characteristics in the nightglow. The nightglow emission line profiles, measured in the equatorial region, have been analyzed using a simple collisional relaxation model. The branching ratio for the dissociative recombination of O_2^+ leading to $O(^1S)$ is inferred. The result shows that the $O(^1S) + O(^1D)$ channel is favored over the $O(^1S) + O(^3P)$ channel by factor of 4 in disagreement with the ratio previously reported by Hernandez. This result is, however, consistent with the active channel for $O(^1S)$ production being via the $^1\Sigma_u^+$ repulsive state of O_2 as suggested by the theoretical calculations of Guberman. A value for the excitation exchange cross-section for $O(^1S)$ of $2.45 \pm 0.8 \times 10^{-16}$ cm^2 is obtained. (Dissociative recombination, line profiles).
J. Geophys. Res., Blue, Paper 3A1382

5505 Airglow
THE O^+ 834 Å DAYGLOW: SATELLITE OBSERVATIONS AND INTERPRETATION WITH A RADIATION TRANSFER MODEL
Shailendra Kumar (Space Sciences Center, University of Southern California, Los Angeles, CA 90089-1341), S. Chakrabarti, F. Paresce and S. Bowyer
The O^+ 834 Å dayglow observations made with the EUV spectrometer on the Air Force satellite STP-78-1 are interpreted with the use of a radiation transfer model. At 600 km altitude the dayglow intensity was observed to vary with magnetic latitude from 30 R to 300 R in the near zenith direction (θ = 40°) and from 400 R to 500 R in the near nadir direction (θ = 140°); the correspondingly large near zenith to near nadir intensity ratio of 0.1 – 0.65 over much of the dayside indicates that the O^+ ions in the topside ionosphere constitute an optically thick medium for resonance scattering of 834 Å airglow emission even at this high altitude. Simultaneous measurements of the O^+ density from the AE-E spacecraft at 400 km altitude near the equator are used to normalize the STP-78-1 airglow data. A g-value of 1.1×10^{-8} s^{-1} at zero optical depth is required for the ionization excitation of atomic oxygen leading to the production of O^+ atoms in ^4P state. The latitudinal distribution of O^+ density derived from the 834 Å airglow data shows a double peak (at ± 13° Lat) surrounding an equatorial trough, characteristic of the equatorial anomaly, at altitudes below 1000 km and a single peak at the magnetic equator above 1000 km. At high latitudes (> 20°), the O^+ densities in the summer hemisphere are substantially lower than those in the winter hemisphere.
J. Geophys. Res., Blue, Paper 3A1310

5515 Auroras
AN ANALYSIS OF THE SPATIAL DISTRIBUTION OF DAYSIDE CLEFT OPTICAL EMISSIONS
R. Link, J.C. McConnell and G.G. Shepherd (Centre for Research in Experimental Space Science, York University, Toronto, Canada M3J 1P3)
An analysis of measurements of the 4278 Å, 5200 Å, 5577 Å and 6300 Å emissions obtained from a rocket launch through the post-noon dayside cleft into the polar cap ionosphere is reported. The 4278 Å and 5577 Å emissions show a clearly defined decrease in intensity at the poleward edge of the dayside particle precipitation, while the 5200 Å emission extends well into the polar cap with only a slight decrease in intensity. The 6300 Å emission displays a behaviour intermediate between these extremes. The optical data are analysed using a dynamical model of dayside cleft auroral processes incorporating transport by ion and neutral winds. It is concluded that neutral winds are responsible for modifying the spatial distribution of the 5200 Å and 6300 Å emission, while the ion drift component is negligible. In addition, it is found that: (1) 80% of the 4278 Å emission intensity is due to resonance fluorescence in the sunlit cleft ionosphere, (2) the reaction $N(^2D) + O \rightarrow NO^+ + O(^1S)$ is consistent with the 5577 Å data if the yield of $O(^1S)$ from the dissociative recombination of O_2^+ is about 24, and (3) the rate of the reaction $N_2^+ + O \rightarrow NO^+ + N$ is apparently higher in the ionosphere than indicated by the laboratory measurements. (Cleft, neutral winds, emissions).
J. Geophys. Res., Blue, Paper 3A1289 8/30

5520 Electric fields
COMPARISON OF THE CHARACTERISTICS OF POTENTIAL-DROP AND CURRENT-DRIVEN DOUBLE LAYERS
N. Singh (Center for Atmospheric and Space Sciences, Utah State University, Logan, Utah, 84322), R. W. Schunk
The characteristics of double layers driven by an applied potential drop and by an injected current into a plasma are compared. In the latter case the potential drop across the double layer appears because of the formation of a virtual cathode. The double layers formed by the two mechanisms show striking similarities with regard to their structure, temporal evolution, and dynamics. However, in the case of current-driven double layers a large energization of ions trapped in the virtual cathode region is observed. Such a large energization of trapped ions is not seen in the case of the potential-drop driven double layers. The interrelation between the field-aligned currents and potential drops for the auroral plasma is discussed. For current-driven double layers, it is found that the current density $J_o \propto \phi_o^{1/2}$, where ϕ_o is the potential drop.
J. Geophys. Res., Blue, Paper 3A1311

5535 Interactions between waves and particles
THERMOSPHERIC CONTROL OF THE AURORAL SOURCE OF O^+ IONS FOR THE MAGNETOSPHERE
M Lockwood (Radio Research Centre, Auckland University, Auckland, New Zealand)
Linear theory, model ion-density profiles and MSIS neutral thermospheric predictions are used to investigate the stability of the auroral, topside ionosphere to oxygen cyclotron waves: variations of the critical height, above which the plasma is unstable, with field-aligned current and thermal ion densities and exospheric temperature are considered. In addition, probabilities are assessed that interactions with neutral atomic gases prevent O^+ ions from escaping into the magnetosphere, after they have been transversely accelerated by these waves. The two studies are combined to give a rough estimate of the total O^+ escape flux as a function of the field-aligned current density, for an assumed rise in the perpendicular ion temperature. Charge exchange with neutral oxygen, not hydrogen, is shown to be the principle limitation to the escape of O^+ ions, which occurs when the waves are driven unstable down to low altitudes. It is found that the largest observed field-aligned current densities can heat a maximum of about 5×10^{14} O^+ ions m^{-2} to a threshold above which they are subsequently able to escape into the magnetosphere in the following 0.5 seconds. Averaged over this period, this would constitute a flux of 10^{15} m^{-2} s^{-1} and in steady-state the outflow would then be limited to about 10^{13} m^{-2} s^{-1} by frictional drag on thermal O^+ at lower altitudes. Maximum escape is at low plasma density unless the O scale height is very large. The outflow decreases with decreasing field-aligned current density and, to a lesser extent, with increasing exospheric temperature. Upward flowing ion events are evaluated as a source of O^+ ions for the magnetosphere and as an explanation of the observed solar cycle variation of ring current O^+ abundance.
J. Geophys. Res., Blue, Paper 3A1264

5545 Ionospheric disturbances
CO-ORDINATED STUDY OF SUB-KM AND 3-METER IRREGULARITIES IN THE F-REGION GENERATED BY HIGH POWER HF HEATING AT ARECIBO
Santimay Basu (Emmanuel College, Boston MA 02115), Sunanda Basu, S. Ganguly and W.E. Gordon
High power high frequency transmitters near Arecibo were used to generate artificial ionospheric irregularities in the F region. Radio star scintillation observations at 430 MHz were performed at Arecibo Ionospheric Observatory with the 305-meter antenna and radar backscatter measurements at 50 MHz were simultaneously made from Guadeloupe Island to probe the sub-kilometer and 3-meter irregularities in the heated volume. Scintillation studies indicate a low frequency modulation of the faster intensity fluctuation structure. By the use of plasma drift data, this low frequency temporal structure translates to spatial dimensions of 1-2 km. The frequency of the modulation envelope is found to be controlled by the heater power and is related to the dominant irregularity wavelength generated by the self-focusing instability. Scintillation spectra imply a steep power-law index of -5 in the scale-length range of about 300 m to 150 m and a shallow index of -2 at less than 150 m. The steep power-law index may arise from an aperture averaging effect of the large 305-meter antenna at Arecibo. Simultaneous measurements of 430 MHz scintillations and 50 MHz radar backscatter from field aligned striations were performed to show that sub-kilometer irregularities can be generated by both O- and X-mode heating whereas the 3-meter irregularities are excited only by the O-mode heating as is predicted by the theories of self-focusing and parametric instability. The width of the 50 MHz echo Doppler spectra is observed to be very narrow being only ~2-3 Hz and independent of the background plasma drift implying that the frequency bandwidth of the scattered signal is probably controlled by the instability process. (Ionospheric modification, scintillations, radar backscatter, Doppler spectra).
J. Geophys. Res., Blue, Paper 3A1336

5545 Ionospheric Disturbances
INCOHERENT SCATTER OBSERVATIONS OF AN ARTIFICIALLY MODIFIED IONOSPHERE
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The launch of NASA's HEAO-C satellite by an Atlas/Centaur rocket on 20 September 1979 provided the "experiment-of-opportunity" to test incoherent scatter radar techniques for the diagnostic study of a chemically-induced modification of the ionosphere. The cause of the disturbance was the rocket's exhaust cloud of H_2 and H_2O molecules that cause a rapid recombination of the F-region plasma at heights above 250 km. The launch from the Kennedy Space Center (28°N, 81°W) was monitored by the Incoherent scatter radar at Millstone Hill (42.6°N, 71.5°W) using low elevation angle observations over ranges exceeding 2000 km. The experiment employed various pulse lengths, integration times and scanning modes to explore optimization methods for an upcoming series of Space Shuttle induced ionospheric hole experiments. The results from the HEAO-hole campaign include the first unambiguous observations of a gas expansion "snowplow effect," the derivation of local and height-integrated plasma recombination rates, and the full spatial, temporal and dynamical morphologies of a large-scale ionospheric hole. The campaign succeeded in demonstrating that incoherent scatter radars can play a primary role in space plasma physics "active experiments" during the next decade.
J. Geophys. Res., Blue, Paper 3A1426

5580 Particle and Fields - Interplanetary Space
HEATER ENHANCED TOPSIDE PLASMA LINE
S. Ganguly and W. E. Gordon (Space Physics and Astronomy Department, Rice University, Houston, Texas, 77251)
In a recent experiment at Arecibo, the ionospheric topside plasma line was enhanced by the high power, high frequency, radiowave, HF heater. The enhancement was a few orders of magnitude over the normal daytime photoelectron-enhanced plasma lines. This is the first observation of an orders of magnitude enhancement of the plasma line in the topside ionosphere induced by the heater. The critical frequency to the F-region (f_oF_2) was reasonably close to (approximately 10% higher than) the HF heater frequency of 5.1 MHz. Possible explanations include propagation via the magneto-ionic Z-mode with some unknown excitation mechanism, some severe inhomogeneities in the ionosphere, or heater excited electrons streaming upward along the magnetic field lines to excite the plasma. Geophys. Res. Lett., Paper 3L024

5580 WAVE PROPAGATION
SIMULATION OF WIDE BANDWIDTH SIGNALS THAT HAVE PROPAGATED THROUGH RANDOM MEDIA
Dennis L. Knepp, (Mission Research Corporation, P.O. Drawer 719, Santa Barbara, CA 93102), Leon A. Wittwer
A numerical technique is described to generate realizations of the received signal after propagation of a wide bandwidth waveform through a layer of strongly turbulent media. These signal realizations are generated to have Rayleigh amplitude statistics and to have spatial and frequency correlation properties which obey the parabolic wave equation in the strong scatter limit. This technique is based upon the solution for the two-frequency mutual coherence function, Γ, for spherical wave propagation with transmitter and receiver located on opposite sides of a finite layer of ionized electron density irregularities. An analytic solution may be obtained for Γ in the strong scatter regime by use of the quadratic approximation for the phase structure function. The thin phase-screen approximation to the thick layer is then utilized, and great simplification to the analytic expression for Γ is obtained. The relationship between the impulse response function of the propagation channel and the two-frequency mutual coherence function and its Fourier transform is then used to directly obtain statistical realizations of wide bandwidth signals. These statistical realizations may be used as direct input to digital receiver modems to represent the effect of propagation through an ionospheric environment disturbed by barium releases or other sources of enhanced ionization. Although these statistical signal realizations apply only to the case of strong scattering, their generation requires only a fraction of the computer resources required for signal generation by wide bandwidth multiple phase-screen calculations. (Scintillation, random media, time-delay jitter).
Rad. Sci., Paper 3S1387

5599 General (Photoelectron Spectra)
THE 2-5 eV ENERGY SPECTRA OF THERMOSPHERIC PHOTOELECTRONS: MEASUREMENTS IN APPARENT CONFLICT WITH THEORY
W.J. McMahon (Air Force Geophysics Laboratory, Hanscom AFB, Bedford, Massachusetts, 01731), L. J. Heroux
The existence of marked structure in the 2-5 eV energy spectra of near earth ionospheric photoelectrons has been predicted by theory and observed by experiment. This structure, arising from resonant vibrational excitation of N_2, is seen as a valleylike dip in the spectra near 2.5 eV and is predicted to be most prominent at low altitudes (310 km), then to diminish with increasing altitude until it disappears in the 200-250 km region. All measurements to date indicate that the overall magnitude of this valley or dip is significantly less than that predicted by theory, but confirm a trend toward diminishing prominence with increasing altitude above about 150 km. Below 140-150 km, however, the valley is observed in the present data to also diminish with decreasing altitude, a reversal of the predicted trend. The present measurements include the only observations, to our knowledge, of this spectral structure below 140 km and these indicate that its maximum prominence occurs in the 143-150 km altitude region, below which it is consistently observed to decline rapidly in magnitude. Recent refinements of theory may lead, in part, to an explanation of these discrepancies. The experimental results are summarized and the difficulties peculiar to space vehicle measurements of very low energy ambient electrons are examined. (Thermospheric photoelectrons, particle measurements, photoelectron spectra).
J. Geophys. Res., Blue, Paper 3A0197

Particles and Fields—Magnetosphere

5705 Bow Shock Waves
TEMPORAL DEVELOPMENT OF DIFFUSE ION EVENTS UPSTREAM OF THE EARTH'S BOW SHOCK: THE 31 OCTOBER 1977 EVENT
G. Skadron (Physics Department, Drake University, Des Moines, Iowa, 50311), H.A. Lee
We examine the origin of the intensity-time profile characteristic of diffuse ion events upstream of the Earth's bow shock. This profile is believed to result from a rotation of the interplanetary magnetic field which produces a systematic variation in the connection time of field lines with the bow shock. A plateau in ion intensity is formed if the connection time exceeds the time needed to reach equilibrium between the shock acceleration and ion loss processes. This scenario is tested using the 31 October 1977 upstream diffuse ion event for which simultaneous magnetic field and ion intensity data have been published. We analyze this event using a two-dimensional Gleeson-Axford equation to describe the shock acceleration process and a model for shock whose nose serves as a uniform source of ions injected into the acceleration process. Intensity-time profiles are calculated for 30 keV and 120 keV protons for a range of diffusion coefficients, $K_\parallel$ and $K_\perp$, using connection times based upon the shock geometry and the magnetic field data. It is found that the calculated and observed profiles are in good general agreement during the growth phases but diverge during the decay. The best overall fit is achieved with diffusion coefficients, $K_\parallel(30\ keV) \sim 4 \cdot 10^{17}$ cm^2-sec^{-1}, $K_\parallel(120\ keV) \sim 1.2 \cdot 10^{18}$ cm^2-sec^{-1} and $K_\perp(120\ keV) \sim 10^{16}$ cm^2-sec^{-1}. These values also produce cross-field anisotropies at 0430 UT which are in satisfactory agreement with the observed anisotropies.
J. Geophys. Res., Blue, Paper 3A1272

5720 Electric Fields
S3-2 Measurements of Polar Cap Potential
H.A. Doyle (Eagle College Research Center, Weston, MA 02193) and W.J. Burke
A total of 83 dawn-dusk, high latitude passes of the S3-2 satellite have been analyzed for the period August through December, 1976, to determine correlations between the cross polar cap potential (ϕ_{pc}) and various solar wind/IMF parameters. Hourly- and 15 sec.-averaged values of the IMF components and hourly-averaged values of the solar wind velocity were available for 68 of the passes. In 41 (27) of the cases studied, the IMF had a southward (northward) component. Measured potentials ranged from 170 kV during a substorm to 12 kV during two periods of northward IMF. Least squares fits to the data were performed in order to determine the dependence of the polar cap potential on four different electric field models, derived from reconnection theory and from traditionally correlated solar wind/IMF parameters. In each case there is a residual polar cap potential on the order of 40 kV. This suggests either a time delay in the relaxation of the potential when the IMF turns northward and/or processes other than reconnection contribute to the polar cap potential. Total IMF variance and solar wind speed were tested as filters on the data and found to have some significance. Comparisons with similar studies based on measurements from the AE and S3-3 satellites are discussed. (polar cap potential, solar wind/IMF parameters, electric field models, reconnection)
J. Geophys. Res., Blue, Paper 3A1338

5720 Interaction between solar wind and magnetosphere
ELECTRIC FIELD MEASUREMENTS AT THE MAGNETOPAUSE: 1. OBSERVATION OF LARGE CONVECTIVE VELOCITIES AT ROTATIONAL MAGNETOPAUSE DISCONTINUITIES
T. L. Aggson (Laboratory for Extraterrestrial Physics, Goddard Space Flight Center, Greenbelt, MD 20771), P. J. Gambardella and N. C. Maynard
Large convective electric fields of the order of 10 mV/m (sometimes as high as 22 mV/m) are observed at rotational magnetopause discontinuities. These observations were made with the long cylindrical (tip to base-line) probes carried on the ISEE-1 satellite. These electric field observations yield convective velocity magnitudes, $V^* = |E \times B/B^2|$, of the order of 150 km/s. In this V* format some of these observations are similar to the high speed plasma velocity observations that were made at the magnetopause with the plasma experiment carried on the ISEE-1 satellite. It is shown that, for many of these magnetopause crossings, there exist a special moving coordinate system where the observed electric fields vanish. Such a unique reference system is often used in theoretical studies of magnetic discontinuities. This special coordinate system does not move at the local plasma velocity but moves instead at a velocity intermediate between the convective velocity and the local Alfvén velocity. It is used here as a diagnostic tool for the experimental investigation of rotational discontinuities at the magnetopause. (Magnetopause, electric fields, rotational discontinuities, convective velocities).
J. Geophys. Res., Blue, Paper 3A1230

5720 Interactions between solar wind and magnetosphere
MAGNETOSPHERIC PLASMA DRIFTS DURING A SUDDEN IMPULSE
W. Baumjohann (MPI für extraterrestrische Physik, 8046 Garching, W-Germany), O.H. Bauer, G. Haerendel, H. Junginger and E. Amata
An interplanetary shockfront (monitored by the ISEE-1/2 satellite pair) hit the earth's magnetosphere on 17 October 1978 around 0430 UT. The changes in magnetospheric plasma drift and magnetic field associated with this sudden impulse (SI) were measured by GEOS-2. In the equatorial plane near the dawn meridian, after the SI the plasma drift first increased (in an inward direction), followed by an exponential decay. The magnetic field changes were purely compressional with an amplitude increase which also exponentially decayed. This features can be explained by adiabatic (quasi-static) compression of the magnetopause due to the increased solar wind pressure behind the shock front. In addition, both data sets exhibit also the excitation of a highly damped compressional hydromagnetic oscillation by the SI, thus hinting of a second, wave-like component in the compression of the magnetosphere. (Interaction between solar wind and magnetosphere, magnetopause, plasma motion).
J. Geophys. Res., Blue, Paper 3A1356

5739 Magnetopause
THE MAGNETOPAUSE AS A TANGENTIAL DISCONTINUITY FOR LARGE FIELD ROTATION ANGLES
I. Papamastorakis (Max-Planck-Institut für extraterrestrische Physik, 8046 Garching, W-Germany), G. Paschmann, N. Sckopke, S.J. Bame, and J. Berchem
Three passes of the ISEE-1 and -2 satellites through the dayside terrestrial magnetopause are discussed where the magnetopause is identified as a tangential discontinuity. This identification is based primarily on the failure of the plasma and magnetic field data to satisfy the conditions for a rotational discontinuity. In all these cases the interplanetary magnetic field was directed strongly southward and the angles between the fields on the two sides of the magnetopause ranged between 136° and 170°. As this is precisely the field geometry thought to be most conducive for reconnection, one would have expected the magnetopause to be a rotational discontinuity. The simplest explanation of this result would appear to be that the magnetic field orientation is not the only factor controlling the onset of reconnection. However, as our identification of the discontinuity applies only locally, it cannot be excluded that for the magnetic field conditions investigated here, different portions of the magnetopause can be described as tangential and rotational discontinuities simultaneously. (Magnetopause, plasma motion).
J. Geophys. Res., Blue, Paper 3A1425

5535 Plasma Instabilities
THE COUPLING OF SHEAR ALFVÉN AND COMPRESSIONAL WAVES IN HIGH β MAGNETOSPHERIC PLASMA
P.H. Ng and V.P. Patel (Physics Department, University of Denver, Denver, Colorado 80208)

The coupling of the compressional instabilities in a two-component, hot and cold inhomogeneous plasma to the resonant shear Alfvén mode is studied in a slab geometry with straight field lines. The lowest order effect of the field inhomogeneity is incorporated into the dispersion relation by retaining the ∇B drift of the particles. It is found that the high phase velocity compressional mode with $\omega/k_\parallel V_A$ shows insignificant coupling to the shear Alfvén wave while the low phase velocity branch with $\omega/k_\parallel V_A$ shows significant coupling. It is also shown that the coupling factor is of the form $\beta_h n_c/n_h k^2 \rho^2$ so that a more realistic field geometry should be used to model the magnetospheric field in the study of low frequency geomagnetic pulsations.
J. Geophys. Res., Blue, Paper 3A1340

5760 Plasma motion, convection, or circulation
DYNAMICAL INJECTIONS AS THE SOURCE OF NEAR GEOSTATIONARY, QUIET TIME PARTICLE SPATIAL BOUNDARIES
B. H. Mauk (Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20707) and C.-I. Meng
To test our understanding of quasi-stationary magnetospheric particle convection, we address here a particular class of particle feature (plasma drop-outs at n at to 5 keV) observed regularly by near geostationary satellites in the noon to dusk quadrant, often during the apparent absence of recent (hours) substorm activity. At first consideration the feature appears to result from the passage of the satellites towards and into the so called "forbidden zone" of the quasi-stationary particle convection patterns. It is demonstrated here that the energy dispersion of the feature cannot be explained by simple stationary convection models even when loss processes are imposed on those particles which penetrate most closely to the earth. Also, the radial position of the feature does not vary with geomagnetic activity as expected from steady convection models. It is concluded that dynamical processes are responsible. However, models based on the modification of the so-called cross-tail field configuration against initial stationary convection patterns are rejected here because these models preserve the qualitative sense of the energy dispersions of the initial pattern. It is proposed that the spatial structures of past (24 hours), dynamical, night-side particle injections determine to a great extent the character of the feature. It is shown that detailed simulations based on the double-spiralled "injection boundary" concept (used previously to reproduce the fast changing night-time features) reproduce very well the character and dispersion curves of the noon-to-dusk feature by allowing the distributions to evolve for many hours. It is emphasized that the portion of the original injection boundary which gives rise to this feature of interest is the decidedly "non-Alfvénic" portion. Because the low-electron energy dispersions expected from quasi-steady convection are not observed, it is concluded that the dynamical injection with characteristics distinct from those of quasi-stationary convection is at all times an inseparable component of the processes that populate the inner magnetospheric regions ($r < 8\ R_E$ at all local times).
J. Geophys. Res., Blue, Paper 3A1406

5790 Short-period (less than 1 day) variations of magnetic field
RELATION OF COMPRESSIONAL HM-WAVES AT GOES-2 TO LOW-LATITUDE Pc3 MAGNETIC PULSATIONS
K. Yumoto (Onagawa Magnetic Observatory and Geophysical Institute, Tohoku University, Sendai 980, Japan), and T. Saito
Daytime magnetic pulsations observed at synchronous orbit by GOES-2 are analyzed to determine whether there is a candidate for the source of low-latitude Pc3's in the outer magnetosphere. Compressional, radially transverse and azimuthally transverse modes of magnetic pulsations in a wide frequency range exist simultaneously in the outer daytime magnetosphere. The compressional and the transverse modes of the daytime magnetic pulsations observed at GOES-2 are statistically dominant in the Pc3- and in the Pc4-frequency ranges, respectively. Some 70 percent of the compressional Pc3 pulsations at GOES-2 have similar periods to the low-latitude Pc3's observed at San Gabriel Canyon, which is located ~11° west of GOES-2's longitude at L = 1.8. Amplitudes of the compressional Pc3 pulsations at GOES-2 (L = 6.67) are relatively larger than those of the low-latitude Pc3's at SGC (L = 1.8). The transverse pulsations with larger amplitude (δB ≥ 1.0 nT) at GOES-2 can propagate only into the high-latitude ionosphere. The compressional Pc3 pulsations with smaller amplitude (δB < 1.5 nT) at GOES-2 are theoretically expected to propagate across the ambient magnetic field to very low-latitudes in [illegible] with one or more the following: (i) a surface wave at the plasmapause (L_{pp}), (ii) a trapped oscillation of the fast magnetosonic wave in the plasmasphere ($L = 1.7 - L_{pp}$), (iii) a higher-harmonic standing oscillation of the local field line at mid-latitude ($L = 1.0 - L_{pp}$), or (iv) a fundamental standing oscillation at very low-latitudes (L = 1.1 and 1.7 – 2.0). Although further research is needed to clarify the [illegible] and propagation characteristics of the low-latitude Pc3 pulsations, we believe that the compressional Pc3 magnetic pulsation in the outer magnetosphere is a candidate for the source of the low-latitude Pc3 magnetic pulsation. (Low-latitude Pc3, Compressional [illegible]).
J. Geophys. Res., Blue, Paper 3A0895

Physical Properties of Rocks

[illegible]
[illegible]SIONAL CRACK HEALING IN QUARTZ
[illegible] Smith (Department of Geology, Stanford University, Stanford, CA 94305) and Brian Evans
Healing fractured single crystal quartz in the presence of pore fluid at 200 MPa (2 kb) pressure [illegible] and 600°C for various periods resulted in the reorganization of initially planar cracks into arrays of spherical and tubular fluid inclusions, a process termed crack healing. Samples heated to [illegible] for several days with no added pore fluid showed no optically measurable crack healing. The rate of healing in samples with added pore fluids is a function of the temperature, time, initial concentration of silica in the pore fluid and the initial crack dimensions. Several lines of evidence indicate that cracks heal as silica is locally transported by diffusion along the crack surface rather than through the pore fluid. Extensive crack healing occurs at temperatures as low as 400°C in times as short as 1-2 days. Estimation of the thermal activation parameters for crack healing suggest that microcracks in quartz will have geologically short lifetimes at temperatures of [illegible] or greater. (Crack healing, quartz properties, fracture healing, water-mineral interactions).
J. Geophys. Res., Red, Paper 3B1360

[illegible] Fracture and Flow
A MICROCRACK MODEL FOR THE DEFORMATION AND FAILURE OF BRITTLE ROCK
L. S. Costin (Geomechanics Research Division, 1542, Sandia National Laboratories, Albuquerque, NM, 87185)
A continuum model derived from the mechanics of tensile microcracks is presented which describes the deformation of brittle rock. The model employs the assumption that stress and time dependent microcrack growth is responsible for the inelastic deformation. Microcrack growth is assumed to occur by two mechanisms: stress-induced crack growth (time dependent) and stress corrosion (stress and time dependent). From the analysis of individual cracks, a criterion for the initiation of damage (crack growth) is derived. This results in the specification of initial and subsequent damage surfaces in stress space which are similar to yield surfaces in the theory of plasticity. When the stress state is below the damage surface, no stress induced crack growth can take place. For stress states on the damage surface, crack growth accompanies any increase in loading, thus expanding the damage surface. By generalizing the results obtained from the analysis of single cracks, a continuum description of the behavior of an ensemble of cracks in an otherwise elastic body is derived. The resulting constitutive equation is essentially elastic, but accounts for material behavior due to microcrack growth through the evolution of an internal state variable which is a measure of the crack state. The form of the evolution equation for the crack-state parameter is determined from the fracture mechanics analysis of single cracks in rock. Model simulations of time-dependent crack growth and experimental results on [illegible] and triaxial compression tests are presented and the results are compared to the results of similar laboratory tests on Westerly granite. (Tensile fracture, microcracks, stress corrosion, elastic, damage).
J. Geophys. Res., Red, Paper 3B127[illegible]

Seismology

6930 Free oscillations
OBSERVATIONS OF COUPLED SPHEROIDAL AND TOROIDAL MODES
G. Masters (Institute of Geophysics and Planetary Physics, UCSD A 025, La Jolla, CA 92093), J. Park and F. Gilbert
In low frequency seismic spectra the Coriolis force theoretically causes quasi-degenerate coupling of spheroidal and toroidal modes whose spherical harmonic degrees differ by unity and whose frequencies are close. It has been found that the coupling causes clearly observable effects on seismic spectra below 3.0 mHz. Many fundamental toroidal modes have a spheroidal component and vice versa. For example, the $_0S_l$ modes for $l = 8$–22 are significantly coupled to the $_0T_l$ modes for $l = 9$–23. The mean frequencies of pairs of coupled multiplets are repelled and the mean attenuations are averaged. The shifting of complex frequencies must be adequately encompassed in the construction of spherically averaged and aspherical models of the density, elastic and anelastic structure of the Earth. The coupling also causes variations in multiplet amplitudes which result in spectral peaks at toroidal mode frequencies on vertical and radial components and at spheroidal mode frequencies on transverse components. The variations must be taken into account in constructing Green's functions for the study of low frequency source mechanisms. (Peak shifts, frequency repulsion, attenuation averaging, amplitude variation, hybrid multiplets, nearly resonant coupling).
J. Geophys. Res., Red, Paper 3B1411

6940 Phenomena related to earthquake prediction
SPATIAL SEISMICITY VARIATIONS AND ASPERITIES IN THE NEW HEBRIDES SEISMIC ZONE
R. E. Habermann (Cooperative Institute for Research in Environmental Sciences, University of Colorado/NOAA, Boulder, Colorado, 80309)
The term "asperity" has been used in many recent studies to describe sections of faults with higher strength than the surrounding zones. The level of background seismicity expected in such zones is unclear. They may appear as quiet zones because of high strength or active zones because of high stress. In this work the problem of seismicity levels in asperities is addressed by identifying regions of anomalously high or low seismicity and comparing the locations of those regions with the locations of asperities as determined from other observations. The regions of anomalously high or low seismicity are identified using a quantitative technique which relies on spatial rate comparisons done with the z test for a difference between two means. This technique allows the determination of the significance of spatial rate differences and the uniqueness of zones of outstanding seismicity. Four active zones which make up 10% and eight quiet zones which make up 16% of the length of the New Hebrides seismic zone were recognized using this technique. Asperities in the New Hebrides seismic zone were identified using characteristics which include large event initiation and stopping, clusters of aftershocks and moderate events, foreshock activity, and earthquake stress drops. Eight regions which showed two or more of these characteristics were identified. They make up 34% of the length of the seismic zone. The overlap between the asperities and the active and quiet regions provides a test of possible relationships between these zones. Thirty-four percent of the asperity area is active as opposed to the 10% expected and 6% of the asperity area is quiet as opposed to the 16% expected. This suggests that in the asperities in the New Hebrides seismic zone stress concentration overcomes increased strength and that phenomena other than increased strength can cause seismic quiescence. Nearly all of the asperities in the New Hebrides seismic zone show high background seismicity or high stress drops, which suggests that likely zones of mainshock initiation can be identified using background seismicity.
J. Geophys. Res., Red, Paper 3B1302

6999 General or miscellaneous
TREE-RING INDICATIONS OF UPLIFT AT ICY CAPE, ALASKA, RELATED TO 1899 EARTHQUAKES
G.C. Jacoby (Tree-Ring Laboratory, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964) and L.D. Ulan
Previous studies show that tree-ring analysis can provide information about past major earthquakes. If occurrence of large, prehistoric seismic events and extent of areas affected by such events can be determined by analysis of old-aged trees, this information will be an important addition to the paleoseismological record. Two great earthquakes occurred in September 1899 on the southeastern coast of Alaska near Icy Cape, an area now included within the Yakataga seismic gap. Due to glacial coverage of Icy Bay and the scarcity of observers, any possible uplift at Icy Cape related to these earthquakes was unreported. [illegible] shoreline trees at two sites, [illegible] an abrupt increase in growth and an increase in growth relative to inland trees. The ages of the trees on the lowland seaward of the sample sites are all post-1899. If uplift occurred, a seaward shifting of the shoreline would improve the growth environment of trees growing on the former wave-beaten shoreline and former beach areas might be protected enough for initial afforestation. Other possible causes for tree growth and shoreline changes are considered; however, from the tree-ring evidence, geomorphology and reports of uplift in other parts of the region, it is the authors' interpretation that uplift occurred at Icy Cape related to the 1899 earthquakes. Subsequent accumulation of fluvial and littoral sediments has built out over and around the uplifted area, resulting in the present-day shoreline configuration. The methodologies used in this study have paleoseismological applications to other uplifted, forested, shoreline areas. (Earthquake history, dendrochronology, Alaska).
J. Geophys. Res., Red, Paper 3B1214

6999 General (Crustal Fault Zone)
REGIONAL TECTONIC AND EARTHQUAKE HAZARD IMPLICATIONS OF A CRUSTAL FAULT ZONE IN SOUTHWESTERN WASHINGTON
C.S. Weaver (U.S. Geological Survey, at Geophysics Program AK-50, University of Washington, Seattle, Washington, 98195) and S. W. Smith
The St. Helens seismic zone (SHZ) is a crustal earthquake zone in southwestern Washington that is defined by small to moderate magnitude (2.5 to 5.5) earthquakes and focal mechanisms. This zone, seismically active along a distance of 90 km, is interpreted as a fault zone capable of generating a moderate to large magnitude shallow earthquake. At the northern end of this zone (about 15 km north of the Cowlitz River), a large area of seismic quiescence (for earthquakes above magnitude 3.0) has predominated since 1977. This quiescence leaves open the question whether the SHZ continues northward into southern Puget Sound. Earthquake focal mechanisms along the SHZ indicate nearly vertical strike-slip faulting with the preferred fault planes striking north-south. From these focal mechanisms, we infer that the direction of maximum compression is northeast, approximately parallel with the direction of convergence between the North American and Juan de Fuca plates. We interpret the focal mechanism data as evidence for locked subduction. This tectonic model raises the possibility of a large-magnitude subduction earthquake. Neither the possibility of a moderate-to-large shallow crustal earthquake nor a major subduction event is part of the current earthquake hazard assessment for Washington.
J. Geophys. Res., Red, Paper 3B1351

Social Sciences

7310 Economics
A METHODOLOGY FOR EVALUATION OF FLOOD FORECAST-RESPONSE SYSTEMS, PART 3: CASE STUDIES
R. Krzysztofowicz (Systems Engineering Department, University of Virginia, Charlottesville, Virginia, 22901) and D. R. Davis
Case studies are reported to illustrate a methodology for evaluation of the performance of Flood Forecast-Response (FFR) systems. The methodology concerns specifically the economic evaluation of the effectiveness of riverine flood forecasts as a means of reducing property damage. The case studies include the evaluation of the FFR systems in three communities: Milton, Pennsylvania; Victoria, Texas; and Columbus, Mississippi. The first study is reported in greater detail and then a comparative analysis of all three systems is presented. Also, an example is given of evaluation of the economic worth of flood forecasts from the viewpoint of an individual decision maker. The capability of the methodology as a decision aid is illustrated in the context of several planning problems such as the determination of the economic benefit of an improvement in the forecast system (e.g., installation of weather radar) or in the response system (e.g., increased community preparedness for floods), the development of an optimal response strategy, etc.
Water Resour. Res., Paper 3W1293

7310 Economics
A BAYESIAN MARKOV MODEL OF THE FLOOD FORECAST PROCESS
R. Krzysztofowicz (Systems Engineering Department, University of Virginia, Charlottesville, Virginia, 22901)
A flood forecast process with a discrete time index k is defined as {l(k),h(k)}, where l denotes the current flood level and h denotes the forecasted flood crest. It is a finite, random duration process with the actual flood crest hh being its terminal state: {hh|l(k),h(k)}. This process is modelled as a two-branch Markov chain. Nonstationary transition probability functions are obtained from a Bayesian information processor which can be imbedded in a dynamic programming algorithm that solves an ensuing Markovian decision problem. The lead time and the processing time of the forecasts are represented by their certainty equivalents. The structure of the model is motivated by an analysis of historical flood forecast records. Methods of estimation of the prior probability and likelihood functions are described. The model is intended primarily as a component of a decision methodology for determining the economic value of and the optimal decisions in response to riverine flood forecasts.
Water Resour. Res., Paper 3W1294

7310 General (Farm Water Supply Determinants)
DETERMINANTS OF FARM WATER SUPPLY IN THE LOWER BHAVANI PROJECT, COIMBATORE, INDIA
K. Palanisami (Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, MN 55108), S. R. Subramanian
A study on the determinants of farm water supply was conducted in the Lower Bhavani Project (LBP) Area, in Coimbatore District, Tamil Nadu during 1978-79. The distance of farmer's field from the outlet of the supply channel, size of the farm, number of intervening farmers, social characteristics and possession of wells for supplementing the canal water were the key variables determining the canal water supply at the farm level. Among the variables distance-direct and lateral distances of the supply channel in the Head and Middle portions and direct, lateral and sublateral distances in the Tail portion markedly influenced the stress days and yield of paddy crop. The build up of stress days was higher at the direct distance category. The results indicated that under the current method of allocating water to only half of the command area in each year, and the consequent water distribution problems, changes in the system of water distribution below the outlet would have more significant impacts on farm level water supply in the Lower Bhavani Project than changes above the outlet. However, the methods suggested to improve the system performance indicated the need for changes above the outlet also for improving the system's overall performance. (Distance, stress days, yield reduction).
Water Resour. Res., Paper 3W1429

7310 Economics
A METHODOLOGY FOR EVALUATION OF FLOOD FORECAST-RESPONSE SYSTEMS, PART 1: ANALYSES AND CONCEPTS
R. Krzysztofowicz (Systems Engineering Department, University of Virginia, Charlottesville, Virginia, 22901), and D. R. Davis
Determination of the value of flood forecasts at a microeconomic level necessitates the consideration of numerous factors: hydrologic, organizational, behavioral, and economic. Those factors and their interactions are captured in a concept of a Flood Forecast-Response (FFR) system. The forecast system extends from the collection of data through the forecasting of floods to the dissemination of warnings. The response system encompasses decision making by the floodplain dweller and protective actions he takes. A methodology for evaluation of the performance of FFR systems is presented. It concerns specifically the economic evaluation of the effectiveness of riverine flood forecasts as a means of reducing property damage. The methodology is built of (1) a model of the FFR process and (2) a performance theory. The first element provides a comprehensive mathematical description of the physical FFR process which takes place during floodings; it outputs the expected annual losses (cost of protective action plus flood damage) incurred by the floodplain dweller under several scenarios. The second element establishes the performance measures and expresses them in terms of the outputs of the FFR model; the measures consist of values (expected annual reductions of the loss), efficiencies, and expected opportunity losses. This part presents a system analysis of the FFR process, describes the general structure of the methodology, and introduces the performance theory. The second part details the theory, and the third part reports three case studies.
Water Resour. Res., Paper 3W1291

7310 Economics
A METHODOLOGY FOR EVALUATION OF FLOOD FORECAST-RESPONSE SYSTEMS, PART 2: THEORY
R. Krzysztofowicz (Systems Engineering Department, University of Virginia, Charlottesville, Virginia, 22901) and D. R. Davis
A methodology for evaluation of the performance of Flood Forecast-Response (FFR) systems is presented. It is built of (1) a model of the FFR process and (2) a set of performance measures. The FFR process is formulated as a finite, random duration, Markovian decision process which outputs the expected annual loss (cost of response plus flood damage sustained). The sequence of forecasts of the flood crest and the actual river stages are described by a two-branch Markov chain of order one. The decision maker's response is represented by a strategy defined on a three-dimensional state vector and time. The performance measures consist of a value, an efficiency, and an expected opportunity loss for each system component as well as the total system. They are defined on a vector of outputs, each output being computed for a distinct scenario of system operation. Two evaluation models are constructed: (1) for a single decision maker and (2) for an arbitrary collection of decision makers along a reach (e.g., a community).
Water Resour. Res., Paper 3W1292

Solar Physics, Astrophysics, and Astronomy

7710 Solar Physics, Astrophysics, and Astronomy (Corona)
INTERMEDIATE-TERM EPOCHS IN SOLAR SOFT X-RAY EMISSION
S. D. Bouwer (Computer Technology Associates, Inc. 5670 S. Syracuse Circle, Suite 110 Englewood, CO 80111)
Observations of the daily 1-8Å X-Ray emission from 1977 to 1981 are analyzed from a terrestrial viewpoint. A high-resolution method of anharmonic frequency analysis is used to search for discrete frequencies in a finite time series and estimate the frequency, phase, and amplitude of each periodic component. The time series data are the broadband full-disk X-ray measurements, primarily from the GOES-2 satellite, and are reduced from 3 second data to a daily nonflare index representing background coronal emission. Intermediate-term epochs are weakly stationary time intervals about 128 days long, corresponding to major intervals of solar activity over about 4.5 rotations. Time series of background X-ray flux longer than about 128 days are nonstationary. Results suggest that near the boundary of an epoch the amplitude spectrum undergoes an episodic change in frequency, phase, and amplitude, after which a new spectrum appears that persists for the duration of the next epoch. Furthermore, those frequencies most closely corresponding to solar rotation are not normally distributed about a 27-28 day mean, but occur at about 22, 25, and 34 days. (Solar X-Rays, Anharmonic Frequency Analysis, Solar Rotation)
J. Geophys. Res., Blue, Paper 3A1163

7740 Magnetic fields (Solar Physics, Astrophysics and Astronomy)
ASYMMETRY IN GEOMAGNETIC FIELD RESPONSE TO SOLAR DISTURBANCES
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We show that the geomagnetic field is more prone to disturbances around the June solstice than around the December solstice, as evidenced from a larger enhancement in geomagnetic activity indices a_p, a_a and a_m following the onset of transient solar disturbances occurring in the 3-monthly period around June solstice than in the interval around December solstice. Further, an asymmetry between the northern and southern hemisphere geomagnetic activity is shown to exist, independent of the level of the activity. This asymmetry, represented by $(a_n - a_s) / (a_n + a_s) / 2$ shows a regular annual variation with a maximum of 60% around June solstice, and is almost absent around the December solstice.
J. Geophys. Res., Blue, Paper 3A1392

7760 Radioastronomy
SOURCE LOCALIZATION OF SATURN KILOMETRIC RADIO EMISSION
A. Lecacheux and F. Genova (LA CNRS 324, Groupe Décamétrique, Observatoire de Meudon, 92190 MEUDON).
From Voyager 1 and 2 – near and far – encounter data, very precise localization of the sources of Saturn radio emission is found with no a priori hypothesis on the emission directivity, by assuming only that there are two sources of emission, each emitting in one circular polarization, and that the global variations of the polarization are due to occultations of the sources by the planet. This and the previous localization results do not allow one to decide between various models of the emission source.
J. Geophys. Res., Blue, Paper 3A1015

Tectonophysics

8170 (Structure of the lithosphere)
DENSITY AND SIZE DISTRIBUTION OF SEAMOUNTS IN THE EASTERN PACIFIC INFERRED FROM WIDE-BEAM SOUNDING DATA
T. H. Jordan (Scripps Institution of Oceanography, La Jolla, CA 92093) H. W. Menard and D. K. Smith
Theoretical expressions relating the distribution of apparent seamount heights per unit length of ship track to the distribution of actual seamount heights per unit area of sea floor are derived for both narrow-beam and wide-beam echosounders. The shapes of seamounts are approximated as truncated right-circular cones of constant slope ε, height-to-radius ratio ξ, and flatness f; i.e., a seamount of basal radius r has a height h=ξr, a flat top of radius fr, and a slope angle of ε = arctan [illegible]. The set of all seamounts in a given physiographic province is assumed to be a Poissonian ensemble specified by a function ν(h), the average number of seamounts per unit area for which r ≥ h. A simple choice for the size distribution of seamounts, and one shown to be consistent with data in the eastern Pacific, is to specify that it decays exponentially with h: $\nu(h) = \nu_0 \exp(-\beta h)$. In the case of a profile of length L taken in water of depth D with a wide-beam echosounder (half-beamwidth [illegible]), the shallow-slope, deep-water approximation [illegible] yields that the expected number of seamounts with apparent heights $\tilde{h} \geq H$ is

[illegible]

We apply this sampling theory to apparent-height data measured from 44,020 km of wide-beam profiles on Pacific crust of post-Mesozoic age. Although the spatial distribution of seamounts in the eastern Pacific is certainly not Poissonian, the abundance statistics do not involve spatial correlations, and we show they are robust with respect to deviations from the Poisson model, provided the statistics are interpreted as averages over the area actually sampled by the track lines. The observed fall-off of apparent heights in the eastern Pacific is very nearly exponential, justifying our use of an exponential model of seamount size distribution. The shape parameters are estimated from multi-beam surveys of Pacific seamounts; an analysis of 10 features in the height range 200-4000 m yields ξ = 0.21 ± .011 and f = 0.21 ± .028. Using these parameters we obtain $\nu_0 = (4.8 \pm 1.1) \times 10^{-9}$ m^{-2} and $\beta = (6.3 \pm 0.8) \times 10^{-3}$ m^{-1}. These values imply that per 10^6 km^2 in the eastern Pacific there are 1600 ± 400 seamounts with summit heights greater than 300 m and 200 ± 40 greater than 1000 m; integrated over the entire size distribution, seamounts occupy about 6% of the sea-floor area and constitute about 0.5% of the oceanic crustal volume. Our estimates of seamount abundance are appreciably greater than those of most other authors, a discrepancy we attribute primarily to the sampling bias of previous studies, which generally used uncorrected map counts. This hypothesis is corroborated by a comparison of our statistics with map-count data for seamounts of heights exceeding 2000 m compiled for the eastern central Pacific from the [illegible] charts; above 3000 m the map counts are consistent with the predictions of the exponential model, but below this height they are biased to low values.
J. Geophys. Res., Red, Paper 3B1410

8170 Structure of the Lithosphere
SOME COMMENTS ON TWO-LAYER EXTENSIONAL MODELS FOR THE EVOLUTION OF SEDIMENTARY BASINS
S. J. Hellinger and J. G. Sclater (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139)
Simple extensional models that involve listric faulting in the brittle upper crust and plastic flow in the lower lithosphere have been shown to account for the subsidence history of various continental sedimentary basins and continental shelves. In this paper we present structural evidence that extension in the continental lithosphere during rifting is not uniform. We review evidence that the rifting process in major intracratonic rift basins is spasmodic rather than continuous, that extension and subsidence within the rift during a tectonic phase is generally accompanied by uplift and erosion of the rift flanks, that subcrustal heat input during rifting occurs over an area much broader than the rift proper and that there may be broad regional uplift before and/or during rifting.
To explain the uplift of the flanks during rifting and their post-rift subsidence we invoke two mechanisms: subcrustal thinning by extension below the flanks and tilted major normal faults in the crust between graben and flanks. The uplift and erosion of the flanks due to tilted faults probably does not significantly affect estimates of extension from subsidence analysis but uplift due to both sources can, in certain cases, be incorrectly attributed to regional uplift or doming.
We present a simplified analysis of the two-layer extensional model for the elementary case in which extension is instantaneous and the crust is thinned by a different amount from the subcrustal lithosphere. We provide a simple graphical method of data analysis to obtain the parameters that describe thinning of the crust and lithosphere during extension from the subsidence history. Application of this method to the central part of the Pattani Trough in the intracratonic Gulf of Thailand shows that extension and thinning of the lithosphere of a factor of ~2 since Late Eocene can account for much of the subsidence history and the present-day heat flow. Our analysis suggests that thinning of the crust in this area is ~20% greater than thinning of the whole lithosphere.
Assuming that none of the lithosphere is removed from the region of extension during rifting, we show by simple geometric examples that a process of non-uniform extension implies that much greater thicknesses of sediment can be deposited in the center of a young basin than in the case of uniform extension of both crust and subcrustal lithosphere. Such an extensional process produces significant uplift of the flanks of the rift and, as a result of erosion of the uplifted areas, the effective cross sectional area of the basin can be increased by as much as 10 to 20%, depending on the rate of erosion, compared to the area that would have been created by a process of uniform extension. Finally, we show that it may ultimately be possible to compute erosion rates from seismic cross sections of basins.
J. Geophys. Res., Red, Paper 3B1068

8199 General (State of Stress)
STRESS ESTIMATE FOR THE HIGHEST MOUNTAIN SYSTEM IN JAPAN.
Toshio Fukao (Department of Earth Sciences, Nagoya University, Nagoya 464, Japan), Koshun Yamaoka
The Hida range, the largest mountain system in Japan, is a contemporary uplifting feature (uplifting rate ~1-5 mm/yr). No large earthquakes nor active faults have been located in this mountain range but small earthquakes occur rather frequently, often as swarms, in its axial portion. Their focal mechanisms are found to be of strike slip type with the P axes in the NW-SE to WNW-ESE direction. This direction is perpendicular to the trend of the mountain chain and coincides with the orientation of the tectonic compression now causing intraplate earthquakes in most regions of the Japanese islands. It also coincides with the convergence direction of the Pacific plate and the Eurasian plate. The Bouguer anomaly profile across the Hida range suggests an upper crustal root beneath it. A buoyancy load associated with this upper crustal root is calculated from the Bouguer anomaly profile, which is found to be not large enough to sustain the surface topographic load isostatically. If any tectonic forces were removed from the mountain system, mountains would subside through inelastic deformation. A formula is presented to calculate, using the known topographic load and buoyancy load, the stress differences arising at the virtual instant of removal of tectonic forces. The Newtonian fluids of uniform viscosity are assumed. The calculated stress The calculated stress difference is horizontally tensile, about 290 bars, at the axial portion of the mountain range. This horizontal tension must be overcome tectonically to ensure the mountain uplifting and the earthquake occurrence. We suggest that the Hida range is now uplifting by horizontal compression of plate tectonic origin with a compressive stress at least of the order of 300 bars. During uplifting, the mountain system seems to maintain its upper crustal configuration as the one in a fairly close state of minimum stress difference. (Seismicity, focal mechanism, gravity, mountain building, tectonic stress).
Tectonics, Paper 3T1086